TECHNICAL MEMORANDUM NO. 5

HUMAN HEALTH RISK ASSESSMENT
903 PAD, MOUND, AND EAST
TRENCHES AREAS
OPERABLE UNIT NO. 2
EXPOSURE SCENARIOS

DRAFT FINAL

ROCKY FLATS PLANT

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT DEPARTMENT

U/NU

BY D20

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1.0 INTRODUCTION

This Exposure Assessment Technical Memorandum (EATM) is presented as part of the Baseline Risk Assessment (BRA) for the 903 Pad, Mound, and East Trenches areas, otherwise known as Operable Unit Number 2 (OU-2), located at the Rocky Flats Plant (RFP). The BRA consists of the Human Health Risk Assessment (HHRA) and the Environmental Evaluation (EE). This technical memorandum has been developed to address the HHRA portion of the BRA for OU-2. The HHRA will evaluate human health risks for on-site and off-site receptors under current land-use conditions and under future land-use conditions, assuming no remedial action takes place at OU-2. This memorandum describes present, future, potential and reasonable use exposure scenarios to be evaluated for OU-2 and identifies reasonable maximum intake parameters for estimating chemical intake via these pathways. This memorandum is being submitted prior to initiating the HHRA for OU-2, as part of the Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI). The RFI/RI is pursuant to the U.S. Department of Energy (DOE) Environmental Restoration (ER) Program (formerly known as the Comprehensive Environmental Assessment and Response Program [CEARP]); a Compliance Agreement between DOE, the U.S. Environmental Protection Agency (EPA), and the State of Colorado Department of Health (CDH), dated July 31, 1986; and the Federal Facility Agreement and Consent Order (FFACO), known as the Interagency Agreement (IAG 1191).

1.1 OBJECTIVES

The objectives of this EATM are to identify: (1) human receptor populations that may be exposed to chemicals released from the site, (2) complete exposure pathways by which chemicals are transported from sources to human exposure points, (3) the route(s) of chemical intake, and (4) intake parameters for each potentially contaminated medium (e.g., soil, water, air). This EATM does not quantify chemical intake. The magnitude of exposure is dependent on the chemical concentration at the exposure points, which will be estimated based on the analytical results of the Phase II Site Investigation and fate and transport modeling, as appropriate. The exposure assessment focuses on media (soil, water, and air) that potentially contain chemicals related to identified sources, identified exposure pathways, potential receptors, exposure points, and factors for potential human intake of impacted media.

1.2 SCOPE

The scope of this technical memorandum is limited to the identification of current and future human exposure scenarios for OU-2, including identifying exposure pathways and intake routes. Potential scenarios are identified according to the Environmental Protection Agency (EPA) concept of reasonable maximum exposure (RME), defined as the highest exposure that is reasonably expected to occur at a site (EPA 1989a). The term "potential" is used to mean "a reasonable chance of occurrence within the context of the reasonable maximum exposure scenario" (EPA 1990). Using this approach, potential exposures are evaluated in Section 4.0 using a conceptual site model (CSM). In the CSM, the likelihood of an exposure scenario occurring is classified as significant, insignificant, or negligible (i.e., incomplete). In this document, negligible or incomplete scenarios are those that are unlikely to occur, significant scenarios are those that could conceivably occur, and insignificant scenarios are those that could also occur but are expected to result in relatively lower levels of exposure (i.e., by one or more orders of magnitude) with respect to significant exposure pathways. Thus, in order of increasing credence, the terms range from negligible or incomplete (unlikely to occur) through insignificant (conceivable, though not as important) to significant (conceivable and important when considering exposure). Both significant <u>and</u> insignificant exposure scenarios will be evaluated quantitatively in the HHRA for OU-2.

This EATM is organized as follows: Section 2.0, Site Description, describes site characteristics that potentially impact human exposures. These characteristics include site history, meteorology, geology, and surface and groundwater hydrology. Section 3.0, Potentially Exposed Receptor Populations, identifies the populations that may be exposed to chemicals originating from identified site-related sources. Land uses and exposure scenarios that are most likely to occur, given the site-specific conditions, are identified for quantitative assessment in the HHRA. Section 4.0, Exposure Pathways, discusses the potential release and transport of chemicals from the site, and identifies exposure pathways to be evaluated in the HHRA using a conceptual site model. Section 5.0, Estimating Chemical Intakes, describes the methodology used to approximate the intake of chemicals in various media and identifies chemical intake factors for the calculation of chemical intake by human receptors. Section 6.0 contains the references cited throughout this document.

2.0
SITE DESCRIPTION

The RFP is located on approximately 2,653 hectare (6,550 acres) of federally owned land in northern Jefferson County, Colorado, approximately 26 kilometers (16 miles) northwest of Denver (Figure 2-1). Surrounding cities include Boulder, Superior, Broomfield, Westminster, and Arvada, which are located less than 16 kilometers (10 miles) to the northwest, north, northeast, and southeast, respectively. Within RFP is an approximately 162 hectare (400 acre) Protected Area (PA) or security area surrounded by a buffer zone of approximately 2,489 hectares (6,150 acres). A general description of RFP is presented in this section. For a more detailed description, please refer to the RFI/RI Work Plan for OU-2 (EG&G 1991a).

The Rocky Flats Plant is a government-owned and contractor-operated facility that is part of the nationwide nuclear weapons production complex. RFP was operated for the U.S. Atomic Energy Commission (AEC) from the RFP's inception in 1951 until the AEC was dissolved in January 1975. At that time, responsibility for RFP was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by the Department of Energy (DOE) in 1977. Dow Chemical USA, an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975, when it was succeeded by Rockwell International. On January 1, 1990, EG&G Rocky Flats, Inc. succeeded Rockwell International.

RFP's primary mission has been to produce metal components for nuclear weapons. These components are fabricated from plutonium, uranium, and nonradioactive metals (principally beryllium and stainless steel). Parts made at RFP are shipped elsewhere for final assembly. When a nuclear weapon is determined to be obsolete, components of these weapons fabricated at RFP are returned for special processing to recover plutonium. Other activities at RFP include research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics. Both radioactive and nonradioactive wastes are generated in these research and production processes. Current waste handling practices involve on-site and off-site recycling of hazardous materials, on-site storage of hazardous and radioactive mixed wastes, and disposal of solid radioactive materials at another DOE facility. However, historically, the operating procedures included both on-site storage and disposal of hazardous and radioactive wastes. Preliminary assessments under the ER Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination.

The RFP is currently performing environmental restoration activities and planning for decontamination and decommissioning. In a recent speech given at RFP, the Secretary of the Energy, James Watkins, outlined DOE's plans for the future use of RFP. Watkins characterized RFP as an attractive site for manufacturers and other businesses (Denver Post, June 13, 1992). He indicated that approximately half of the complex could be occupied by private industry within two years (Boulder Camera, June 13, 1992).

A group of local businesses and government representatives, referred to as the Rocky Flats Local Impacts Initiative (RFLII), has been formed to identify and mitigate negative economic impacts associated with the transition currently occurring at the RFP. One of the RFLII's goals is to work with the DOE and local economic development agencies to identify and attract businesses to occupy existing buildings at the RFP (RFLII 1992). To this end, the RFLII recently drafted criteria to be applied in targeting businesses for future occupation of the RFP.

2.1 HISTORY OF OU-2

This Phase II RFI/RI Exposure Assessment Technical Memorandum addresses OU-2, which contains the 903 Pad, Mound, and East Trenches areas located to the east of the RFP security area. Several individual hazardous substances sites (IHSS's) are included in each area. Figure 2-2 shows the locations of these areas, the IHSS's within each area, and the OU-2 boundary. The following sections provide a brief history of OU-2 and summarize preliminary site characterization information. More detailed information, such as depths of contamination and the extent of soil removal at the 903 Lip Site, can be found in the Phase II RFI/RI Work Plan (EG&G 1991a).

The following section is based on the RFP CEARP Phase I Installation Assessment and the RCRA Part B Operating Permit Application as reported in EG&G (1991a). These documents are based on historical records, aerial photography and interviews with RFP personnel.

2.1.1 903 Pad Area

The five IHSS's located within the 903 Pad Area include the following:

- 903 Drum Storage Site (IHSS Ref. No. 112)
- 903 Lip Site (IHSS Ref. No. 155)
- Trench T-2 Site (IHSS Ref. No. 109)
- Reactive Metal Destruction Site (IHSS Ref. No. 140)
- Gas Detoxification Site (IHSS Ref. No. 183)

The 903 Drum Storage Site (IHSS Ref. No. 112) was used from October 1958 to January 1967 for storage of radioactively contaminated oil drums. Contents of the drums included plutonium, uranium, carbon tetrachloride, hydraulic oils, vacuum pump oil, trichloroethylene, perchloroethylene, silicone oils, acetone still bottoms, and ethanolamine.

Drum leakage into the soil was noted at the site in 1964, and corrective action consisted of transferring the contents of leaking drums to new drums and fencing the area to restrict access. The shipment of drums to the 903 Drum Storage Site ended in January 1967, when drum removal efforts began. Removal of all drums and wastes was completed in June 1968.

In November 1968, site grading began in preparation for applying an asphalt cap over the area. This work included moving contaminated soil from around the fenced area to inside the fenced area. Two courses of clean fill material (15 cm of loose gravel and 8 cm of fill dirt) were placed over the site during the late summer of 1969. An asphalt cap (approximately 8-cm thick) was applied in October 1969. In February 1970, additional road-base course material was applied to soils directly east and south of the asphalt pad, due to soil contamination.

The Trench T-2 Site (IHSS Ref. No. 109), located approximately 61 meters (200 feet) south of the 903 Pad area, was used prior to 1968 for the disposal of sanitary sewage sludge and flattened drums contaminated with uranium and plutonium.

During drum removal and cleanup activities associated with the 903 Drum Storage Site, winds redistributed plutonium beyond the pad to the south and east. The highest chemical concentrations were noted at the 903 Lip Site (IHSS Ref. No. 155), immediately adjacent to the pad to the south and southeast. Soil cleanup efforts were undertaken in 1976, 1978, and 1984 to remove plutonium-containing soils from three different areas within the 903 Lip Site. After the first two cleanup efforts, the excavated area was covered with clean top soil and revegetated with native grasses. After the 1984 cleanup was performed, the excavated area was backfilled with clean topsoil.

The Reactive Metal Destruction Site (IHSS Ref. No. 140) was used during the 1950s and 1960s primarily for the destruction of lithium metal (DOE 1986). The residues, primarily lithium carbonate, were buried. Smaller quantities of sodium, calcium, magnesium, solvents, and unknown liquids were also destroyed at this location.

The Gas Detoxification Site (IHSS Ref. No. 183) was used to detoxify various gases from lecture bottles between June 1982 and August 1983. The lecture bottles, used in research and development work, held approximately one liter of compressed gases, such as nitrogen oxides, chlorine, hydrogen sulfide, sulfur tetrafluoride, methane, hydrogen fluoride, and ammonia. Gas detoxicification was accomplished by using various commercial neutralization processes.

2.1.2 Mound Area

The Mound Area includes the following IHSS's:

- Mound Site (IHSS Ref. No. 113)
- Trench T-1 Site (IHSS Ref. No. 108)
- Oil Burn Pit No. 2 Site (IHSS Ref. No. 153)
- Pallet Burn Site (IHSS Ref. No. 154)

The Mound Site (IHSS Ref. No. 113) was used between April 1954 and September 1958 for disposal of drums containing primarily depleted uranium- and beryllium-contaminated lathe coolant. It is likely that some of the coolant also contained enriched uranium and plutonium. Some drums contained perchloroethylene. Cleanup of the Mound Site was accomplished in May 1970, and the materials removed were packaged and shipped to an off-site DOE facility for disposal.

The Trench T-1 Site (IHSS Ref. No. 108) was used from 1954 until 1962. It contains approximately 125 drums filled with approximately 25,000 kg (55,125 pounds) of depleted-uranium chips and plutonium chips coated with small amount of lathe coolant. This trench is now covered with about 0.6 meters (2 feet) of soil and the corners are marked.

The Oil Burn Pit No. 2 Site (IHSS Ref. No. 153) is two parallel trenches that were used in 1957, and from 1961 to 1965, to burn drums of oil containing uranium. The drums used for the oil burning operation were generally reused; however, some empty drums were discarded by flattening and burning them in the trenches. The residues from the burning operations and the flattened drums were covered with backfill. In 1978, the area was excavated to a depth of approximately 1.5 meters (five feet), and the contaminated soil was removed and shipped off site to an authorized DOE disposal site.

The Pallet Burn Site (IHSS Ref. No. 154), southwest of Oil Burn Pit No. 2, was reportedly used to destroy wooden pallets in 1965. The types of hazardous substances or radionuclides that may have been spilled on these pallets is unknown. The site was reportedly remediated and reclaimed in the 1970s.

2.1.3 East Trenches Area

The East Trenches Area consists of nine burial trenches (IHSS Ref. Nos. 110 and 111.1-111.8) and two spray irrigation sites (IHSS Ref. Nos. 216.2 and 216.3). The burial trenches were used from 1954 to 1968 for disposal of uranium- and plutonium-contaminated sanitary sewage sludge and flattened, empty drums contaminated with uranium. The wastes in these trenches have not been disturbed since their burial.

The East Spray Irrigation Sites were used for spray irrigation of sewage treatment plant effluent. Effluent containing low concentrations of chromium was inadvertently sprayed in the area in February and March 1989.

2.2 PHYSICAL SETTING

The natural environment of RFP and its vicinity is influenced primarily by its proximity to the Front Range of the Rocky Mountains. RFP is directly east of the north-south trending Front Range and is located approximately 26 kilometers (16 miles) east of the Continental Divide, on a broad, eastward-sloping plain of coalescing alluvial fans developed along the Front Range at an elevation of approximately 1,850 meters (6,000 feet) above mean sea level. The fans extend approximately 8 kilometers (5 miles) in an eastward direction from their origin at Coal Creek Canyon and terminate on the east, at a break in the slope, to low rolling hills. The operational area at RFP is located near the eastern edge of the fans on a terrace between stream-cut valleys (North Walnut Creek and Woman Creek).

Three intermittent streams drain RFP with flow generally from west to east. These drainages are Rock Creek, Walnut Creek, and Woman Creek. Rock Creek drains the northwestern corner of RFP and flows northeast through the buffer zone to its off-site confluence with Coal Creek. An east-west trending interfluve separates the Walnut and Woman Creek drainages. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the RFP security area. These three forks of Walnut Creek join in the buffer zone and flow toward Great Western Reservoir, which is approximately one mile east of the confluence. This flow is routed around Great Western Reservoir by the Broomfield Diversion Canal operated by the City of Broomfield. Woman Creek drains the southern portion of the RFP buffer zone and flows eastward to Mower Reservoir and Standley Lake.

2.3 METEOROLOGY

RFP has a semi-arid climate and receives an average of approximately 38 centimeters (15 inches) of precipitation annually. Approximately 50 percent of the precipitation is received from snowfall during the winter and spring. Summer thunderstorms account for approximately 30 percent of this moisture, and the remainder is received as light rain and snowfall in the fall. Annually, snowfall averages 216 centimeters (85 inches). Annual free-water evaporation is approximately 114 centimeters (45 inches) (DOE 1992), which is greater than the amount of annual precipitation.

The general annual wind direction, as shown in Figure 2-3, indicates that winds flow from the northwest approximately 46 percent of the year. Wind flows from the west-southwest approximately 7.2 percent of the year. The highest wind velocity is from the northwest and is greater than approximately 56 kilometers per hour (34.5 mph). Therefore, it is likely that atmospheric dispersion from RFP could affect areas to the east and southeast of the plant.

2.4 GEOLOGY

The surficial deposits at OU-2 consist of pediment alluvium, colluvium, valley-fill alluvium, and artificial fill that unconformably overlay bedrock. Surficial deposits at RFP are Quaternary and Pleistocene in age. The near-surface bedrock formations of the Arapahoe and Laramie, as well as the Rocky Flats Alluvium, are shown on Figure 2-4 and are discussed below. The regional dip of the bedrock is approximately two degrees to the east, in the vicinity of OU-2.

The Rocky Flats Alluvium is a pediment gravel deposited in a laterally coalescing alluvial fan environment. It was deposited across a gently sloping erosional surface cut into the underlying soft bedrock. The deposit consists of poorly to moderately sorted, poorly stratified clays, silts, sands, gravels, and cobbles. The colors of the Rocky Flats Alluvium include light to dusky brown, dark yellowish-orange, grayish orange, and dark gray. The Rocky Flats Alluvium ranges in thickness from 0 to 15 meters (0 to 50 feet) beneath OU-2. Subsequent dissection and headward erosion by creeks to the south and north of OU-2 have cut through the alluvium into the underlying bedrock. This dissection has left the base of the alluvium exposed along the valley walls, approximately 12 to 37 meters (40 to 120 feet) above the present valley floor. Remnants of younger terrace deposits of the Verdus and Slocum Alluviums occur at lower elevations in some locations along the valley slopes of OU-2.

Colluvial materials in OU-2 were derived from slope wash and creep of the Rocky Flats Alluvium, and the Arapahoe and Laramie Formations. The colluvium consists of clays, sands, and gravels, and ranges in thickness from 1 to 6 meters (3 to 20 feet). Colluvium derived from the Rocky Flats Alluvium characteristically covers the alluvial/bedrock contact along the hillsides. Artificial fill and disturbed ground occur in localized areas of the 903 Pad, Mound, and East Trenches. Recent valley-fill alluvium occurs in the active stream channels of Walnut and Woman Creeks. This material is derived from reworked older alluvial and bedrock deposits.

The Cretaceous-age Arapahoe Formation unconformably underlies the surficial material at OU-2. The Arapahoe Formation, which is approximately 46 meters (150 feet) thick (EG&G 1991a) in the vicinity of RFP, is the product of a fluvial depositional environment and is composed of channel, point bar, and overbank fluvial deposits of claystones, siltstones, sandstones, and occasional lignitic coal seams and ironstones. The Arapahoe occasionally outcrops along Walnut and Woman Creeks' stream valleys.

The sandstones of the Arapahoe are primarily very fine- to coarse-grained quartz sands, moderate to well-sorted, and subangular to well-rounded. Some clay rip-up clasts and iron nodules are present in the sandstones of the Arapahoe Formation. The colors of the sandstone are light gray to olive gray. The weathered sandstones are mainly dusty yellow to dark yellowish-orange, as a result of iron oxide staining. The colors of the claystones are light to medium gray and dark yellowish-orange when weathered. Individual sandstone lenses, which comprise the fluvial facies of the Arapahoe, are local in extent and may or may not be in hydraulic communication with one another. Multiple, overlapping sandstone sequences exist within the Arapahoe Formation (EG&G 1992a).

The No. 1 Sandstone channel unconformably underlies the Rocky Flats Alluvium and colluvium, and is generally located in the northwest side of the 903 Pad, Mound, and East Trenches areas of OU-2. The No. 1 Sandstone is a heterogeneous sandstone body consisting of sandstone with interbedded siltstone and claystone layers. Medium- to coarse-grained sand and an occasional conglomeratic sandstone have been identified at the base of the No. 1 Sandstone in OU-2. The unit ranges from 0 to 12 meters (0 to 40 feet) in thickness.

The Laramie Formation is Cretaceous in age and gradationally underlies the Arapahoe Formation at OU-2. The Laramie Formation, which is approximately 244 meters (800 feet) thick (EG&G 1991a) in the vicinity of RFP, is divided into two units. The lower unit, which is approximately 76 meters (250 feet) thick, is composed of several sandstone layers and many coal seams. The upper unit, which is approximately 168 meters (550 feet) thick, is composed of deltaic claystones, siltstones, some fluvial sandstones, and an occasional coal layer. The sandstones in the lower unit are light to medium gray, fine- to coarse-grained, poorly sorted, and subangular. The upper unit claystones and siltstones are light olive gray to olive-black in color with some carbonaceous material.

2.5 HYDROLOGY

2.5.1 Upper Hydrostratigraphic Unit (UHSU)

The upper hydrostratigraphic unit (UHSU) at OU-2 consists of the Rocky Flats Alluvium, colluvium, valley fill and the Arapahoe No. 1 Sandstone. In addition, limited areas of subcropping claystone may be saturated, particularly where the claystone is fractured and weathered (EG&G 1991b). Groundwater in the UHSU exists under unconfined conditions. Groundwater flow across the area is generally west to east but local variations occur. Groundwater in the Rocky Flats Alluvium will locally follow the scoured lows on the top of the underlying claystone bedrock, while flow in the No. 1 Sandstone is controlled by the geometry of the sandstone body. (EG&G 1991b). Groundwater in the colluvium mantling the valley slopes bordering OU-2 has a localized flow toward Walnut and Woman Creeks.

Recharge to the UHSU beneath OU-2 is primarily due to precipitation, snowmelt, and water loss from ditches, streams, and ponds. Groundwater levels in the aquifer respond dynamically to seasonal changes and stream and ditch flow. Groundwater levels reach their highest in the spring and early summer and decline the remainder of the year, with periodic changes due to precipitation or irrigation events.

Groundwater discharge in the UHSU occurs at seeps and springs at the contact between the Rocky Flats Alluvium or the No. 1 Sandstone and the claystone bedrock. This water is consumed by evapotranspiration or flows downslope through the colluvial deposits where it primarily discharges to Walnut Creek (northeast of OU-2). Minor discharge to the south interceptor ditch (SID) (southeast of OU-2) and Woman Creek (south of OU-2) also occurs, or groundwater is consumed by evapotranspiration (EG&G 1991b).

Phase I data indicate that chemicals in groundwater are localized in the UHSU below OU-2. Additional characterization of the vertical and horizontal extent of the contamination plume below OU-2 is currently being investigated under Phase II activities. Phase II activities will also provide additional information that will enable a better definition of groundwater movement and better define groundwater/surface water interactions in the OU-2 area (EG&G 1991a).

2.5.2 Confined Groundwater Flow Systems

Groundwater, under confined conditions beneath OU-2, occurs in the Laramie Formation. Flow within individual sandstones is generally from west to east (Robson et al. 1981), but the geometry of the groundwater flow path is not fully understood due to a present lack of information on the continuity of the sandstones and their hydraulic connection (EG&G 1991b). Recharge to this system occurs at outcrop areas exposed to surface water flow and infiltration at outcrops along the Front Range, located approximately 2.4 kilometers (1.5 miles) west of the western edge of OU-2. The confined groundwater system is hydraulically disconnected from the UHSU at OU-2 by an impermeable claystone that varies from 15 to 30 meters (50 to 100 feet) in thickness (Robson et al. 1981).

2.5.3 Surface Water

Surface water at RFP is currently managed and monitored in accordance with the RFP's surface water management plan (EG&G 1991e). The surface water management program at the RFP, which includes a National Pollutant Discharge Elimination System (NPDES) permit, is designed to protect public health and the environment from chemicals that may occur in surface water. This program has been approved by the EPA to provide for treatment of surface water, if necessary, prior to release from the RFP.

Two intermittent streams, Walnut Creek and Woman Creek, are located in the vicinity of OU-2 and generally flow from west to east. Walnut Creek, north of OU-2, flows through a series of detention ponds (A and B series) and is currently diverted around Great Western Reservoir via the Broomfield Diversion Ditch. Woman Creek, south of OU-2, discharges into Mower Reservoir and Standley Lake. These streams are ephemeral because of the seasonal response to freezing, spring runoff, and storm events.

Intermittent groundwater seeps or springs occur near IHSS 140 in the 903 Pad Area, IHSS 154 in the Mound Area, and northeast of the East Trenches Area, along the south side of the Walnut Creek drainage. These areas are currently being remediated as Interim Measures at the RFP (EG&G 1991c). Collected surface water will be treated using cross-flow membrane filtration (for particulate radionuclide removal) followed by liquid phase granulated activated carbon (GAC) filtration (for organics removal). However, the potential contribution of site-related chemicals from these seeps to surface water in the Walnut and Woman Creek drainages will be quantitatively evaluated for the relevant exposure pathways.

Figure 2-2 illustrates the current surface water bodies in the Woman and Walnut Creek drainages. Detention Ponds C-1 and C-2 are located on Woman Creek. Pond C-2 receives flow only from the South Interceptor Ditch (SID), which lies on the northern flank of the Woman Creek drainage between OU-2 and Woman Creek. The SID collects runoff from the southern RFP security area including portions of OU-2. The Pond C-2 flow is not discharged to Woman Creek, but is pumped to the Broomfield Diversion Ditch approximately semi-annually in accordance with the current surface water management program per EPA approval.

Detention Ponds B-1 through B-5 are located on South Walnut Creek and receive surface and groundwater flows from the northern portion of OU-2. Surface water in the Walnut Creek drainage is monitored in accordance with RFP's surface water management plan (EG&G 1991e) and National Pollutant Discharge Elimination System (NPDES) permit, prior to treatment (if required) and discharge from B-3 and B-5.

2.5.4 Domestic Wells Along the South Walnut and Woman Creek Drainages

The groundwater in the UHSU beneath OU-2 is discharged by seeps and springs along the contact between the Rocky Flats Alluvium/Arapahoe No. 1 Sandstone and the underlying bedrock claystones. This water eventually enters the valley fill along the adjoining creeks and migrates downgradient. Off-site wells located in the drainages of Walnut and Woman Creeks are therefore of particular interest since groundwater in OU-2 discharges into these drainages.

Walnut Creek, which is the primary drainage for OU-2, flows eastward and is currently diverted around Great Western Reservoir. Land surrounding the creek drainage outside the RFP boundary and reservoir is used as open space and does not contain residential or commercial developments. No water wells are registered at the Colorado State Engineer's (CSE) office for this area.

Woman Creek drains the southern portion of OU-2 and discharges into Mower reservoir and Standley Lake. Fourteen wells west of Standley Lake are registered in this drainage (Figure 2-5). Table 2-1 lists information from completion reports for these wells that are on file at the CSE Office. Screened depths given for these wells place the completion intervals within the basal Arapahoe to Upper Laramie Formations. The Upper Laramie Formation, in the vicinity of RFP, is described as predominantly claystones with some thin discontinuous sandstone lenses and an occasional coal seam (DOE 1992). The thin, discontinuous character of these sandstones suggest that a hydraulic connection to the alluvium along Woman Creek is unlikely. Also, there are indications that the off-site wells may be hydraulically connected to Standley Lake, a large source of potential recharge (DOE 1992).

2.6 ECOLOGY

The following section presents a brief summary of biological resources at the RFP and is not intended to characterize ecological processes. A more detailed evaluation of ecological processes and potential environmental impacts at the RFP will be presented in the Environmental Evaluation portion of the BRA. The scope of this Technical Memorandum is limited to the evaluation of exposure pathways for the HHRA.

OU-2 contains diverse and unique vegetation. Species of flora representative of tall-grass prairie, short-grass plains, lower mountain, and foothill ravine regions can be found within the boundaries of RFP. Grasses predominantly cover the steep sides of the hillsides along Walnut Creek and Woman Creek drainages. The Walnut Creek and Woman Creek drainages also host grasses, cattails, rushes, and cottonwood trees. Since the acquisition of RFP, vegetative recovery has occurred, as evidenced by the presence of disturbance-sensitive grass species such as big bluestem and side oats grama. No vegetative stresses attributable to hazardous waste contamination have been identified (EG&G 1991b).

The animal life inhabiting RFP and the buffer zone consists of species associated with western prairie regions. The most common large mammal is the mule deer, of which there are approximately 125 permanent residents. A number of small carnivores such as coyote, red fox, striped skunk, and long-tailed weasel are present at RFP. The bird population at RFP includes the western meadowlark, mourning doves, vesper sparrows, great horned owl, and ferruginous and American rough-legged hawks. Many varieties of ducks, killdeer, and redwing blackbirds have been observed near the ponds on Woman and Walnut Creeks. Minnows have been observed in both creeks, and it is possible that other fish may use the creeks, but most likely this would occur only during high-flow periods. Bull snakes and rattlesnakes can be seen on the hillsides of OU-2, while the western painted turtle and western plains garter snake inhabit the greens near the ponds.

Ecological surveys at the RFP performed in compliance with the Threatened and Endangered Species Act indicate the presence of habitat that is potentially suitable to four plant species and several wildlife species of concern. The plant species include the forktip threeawn, Colorado butterfly plant, toothcup, and Diluvium lady's tresses (EG&G 1991d). The wildlife species include the bald eagle, peregrine falcon, whooping crane, and the black-footed ferret (DOE 1991, USFWS 1990). Because of the unique and undisturbed nature of the buffer zone, it is possible that it will receive future designation as an ecological reserve or as a National Environmental Research Park. This is consistent with DOE policy and plans (DOE 1992) and with Jefferson County (Jefferson County 1990) planning as detailed in Section 3.0.

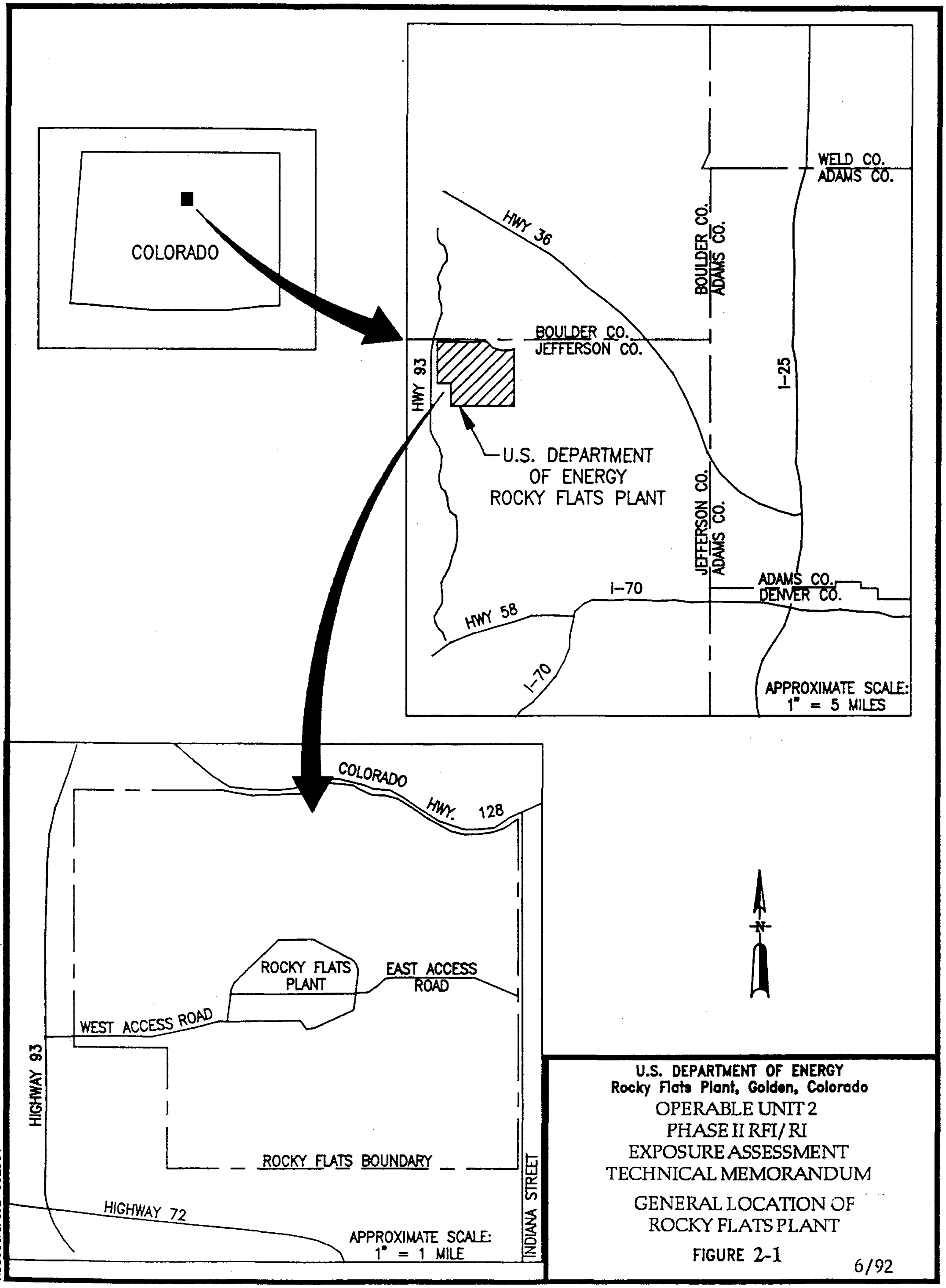
TABLE 2-1

WELLS NEAR WOMAN CREEK*

Permit No.	Yield ** (gpm)	Total Well Depth (ft)	Screened Interval (Feet Below Ground Surface)					
			Top	Bottom	Top	Bottom	Top	Bottom
26	15	125	45	85	105	125	--	--
1246	15	67	37	67	--	--	--	--
8117	12	70	20	70	--	--	--	--
14820	8	200	100	200	--	--	--	--
18383	12	75	50	75	--	--	--	--
19069	6	100	27	36	63	90	--	--
29620	15	112	85	112	--	--	--	--
32849	14	80	23	80	--	--	--	--
45855	15	110	30	110	--	--	--	--
52028	8	122	80	96	--	--	--	--
89558	15	150	30	50	70	90	130	150
96282	14	125	65	90	--	--	--	--
103583	15	125	90	125	--	--	--	--
138834	15	71	20	71	--	--	--	--

* Source: Colorado State Engineer's Office
** Based on drillers' observations. Does not indicate sustainable well yields.
-- Not available

Source: DOE 1992

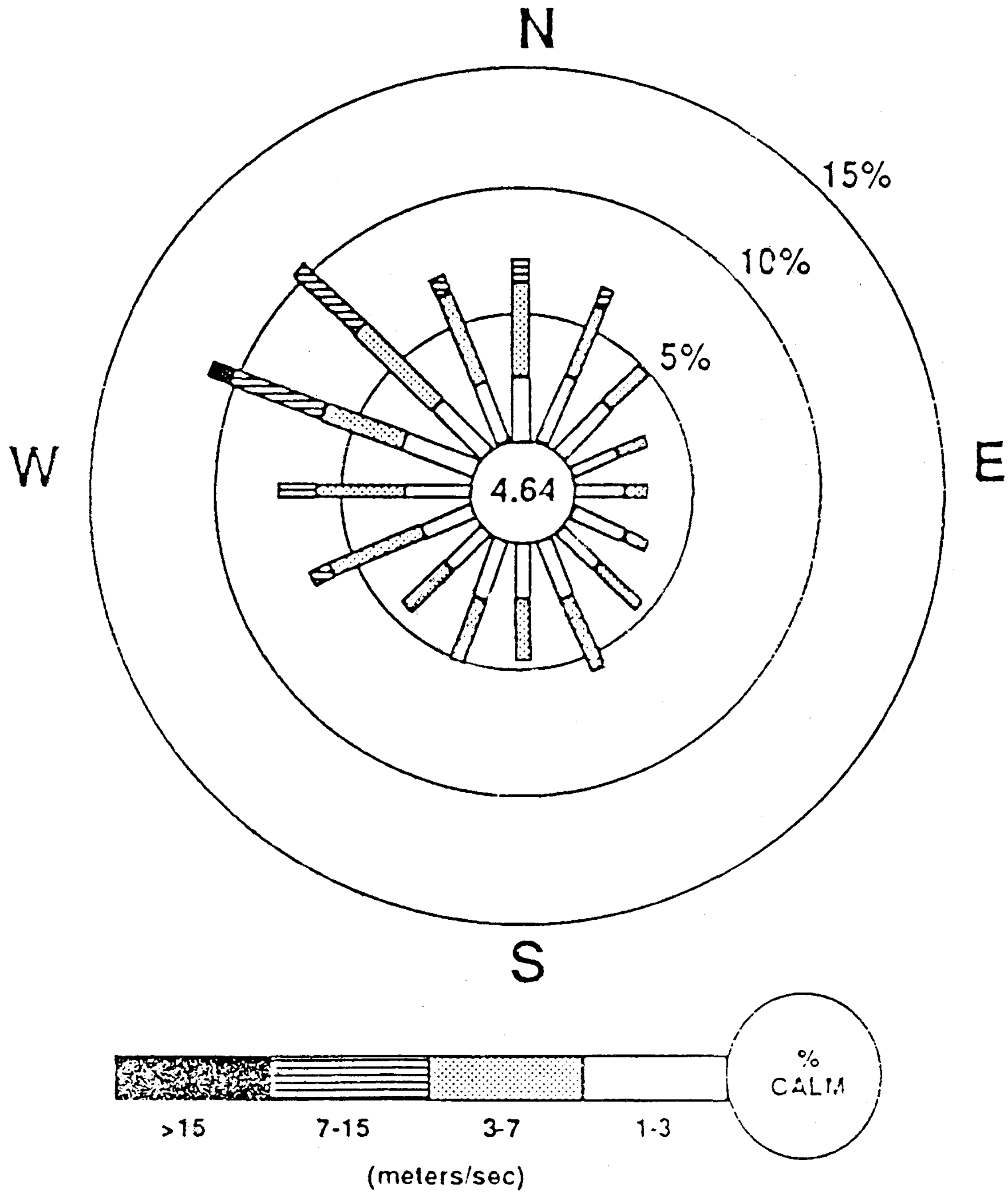


U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT 2
PHASE II RFI/RI
EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

GENERAL LOCATION OF
ROCKY FLATS PLANT

FIGURE 2-1

6/92



SOURCE: EG&G 1990.

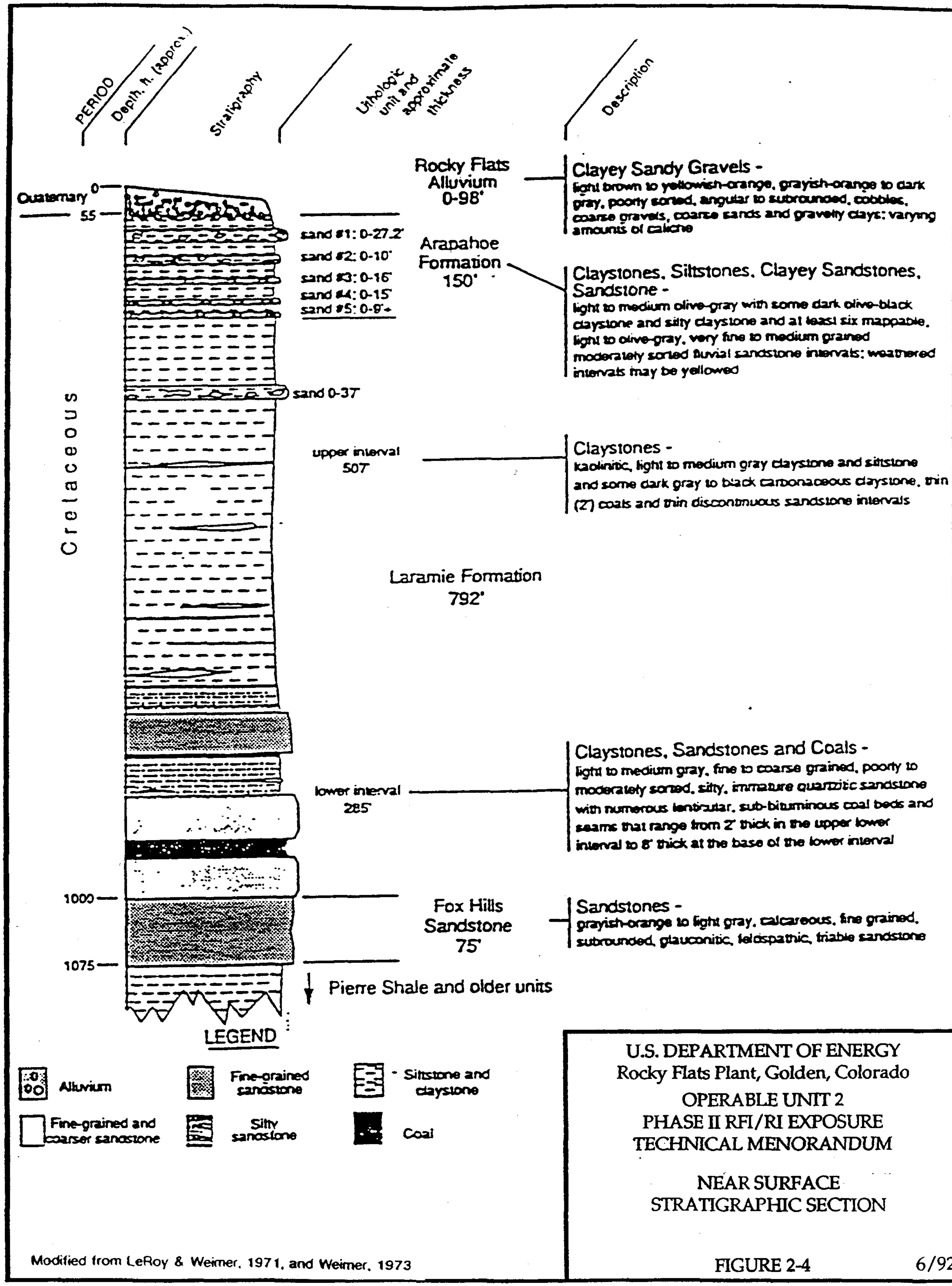
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

WIND ROSE FOR THE
ROCKY FLATS PLANT
1990 ANNUAL

FIG. NO. 2-3 JUNE, 1992

23047023



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE
TECHNICAL MENORANDUM

NEAR SURFACE
STRATIGRAPHIC SECTION

FIGURE 2-4 6/92

3.0 POTENTIALLY EXPOSED RECEPTOR POPULATIONS

The potentially exposed populations were characterized primarily using the "1989 Population, Economic, and Land Use Data for Rocky Flats Plant" (DOE 1990), developed by the Denver Regional Council of Governments (DRCOG). This DRCOG study encompassed an 81-kilometer (50-mile) radius area from the center of Rocky Flats Plant and included all or part of 14 counties and 72 incorporated cities with a 1989 combined population of 2,206,550.

3.1 DEMOGRAPHICS

The Rocky Flats Plant is located in a rural area of unincorporated Jefferson County, approximately 16 miles northwest of Denver and approximately 10 miles south of Boulder. RFP is situated on a 6,550-acre parcel of federally owned land. The plant facility is located in the approximate center of the parcel and is surrounded by a buffer zone of approximately 6,150 acres. The area to the west of RFP is mountainous, sparsely populated, and primarily government-owned. The area east of RFP is generally a high arid plain, densely populated, and privately owned. The majority of the population included in the DRCOG study is located within 30 miles of RFP, to the east and southeast, in the Denver metropolitan area. The majority of the development of the plains to the east of RFP has occurred since the plant was built, and according to projections by DRCOG, future development is expected to continue (DOE 1992).

Within a 6.4-mile radius of the center of RFP, there is little residential or commercial development. Between 4 and 10 miles, development increases, with approximately 316,000 residents within a 10-mile radius. The most significant development exists to the southeast, in the cities of Westminster, Arvada, and Wheat Ridge. The cities of Boulder, to the northwest; Broomfield, Lafayette, and Louisville, to the northeast; and Golden, to the south, also contain significant developments within this 10-mile radius (DOE 1992). The DRCOG study projected populations through the year 2010.

Figure 3-1 (DOE 1990) illustrates the 1989 residential population found within an 8-kilometer (five-mile) radius of RFP. The 2010 projected residential population is illustrated in Figure 3-2 (DOE 1990). Sectors 1 and 2 represent land within the RFP boundary and, therefore, are relevant to on-site scenarios. Sectors 3, 4, and 5 represent property outside of the RFP boundary and are relevant to off-site scenarios. Radial Segments D through I represent the predominant downwind and downstream directions from the OU-2 area and, thus, the areas relevant to exposure scenarios. The 1989 and projected 2010 population data shown in Figures 3-1 and 3-2 are summarized in Table 3-1. The information presented in Table 3-1 indicates that zero population growth is projected in the next 20 years for areas immediately adjacent to the RFP boundary (Sector 3).

The nearest school is Witt Elementary School, which is approximately 2.7 miles east of the RFP buffer zone (EG&G 1991a). All other sensitive subpopulation facilities (e.g. hospitals and nursing homes) are located beyond the five-mile radius from the center of RFP. There are 93 schools, eight nursing homes, and four hospitals within a 10-mile radius of RFP (DOE 1992).

The nearest drinking water supply is Great Western Reservoir, located approximately 2.3 miles to the east of the center of RFP. The City of Broomfield operates a water treatment facility immediately downstream from Great Western Reservoir. This facility supplies drinking water to approximately 28,000 persons. Standley Lake Park, a recreational area and a drinking water supply for the cities of Thornton, Northglenn, Westminster, and Federal Heights, is located 3.5 miles to the southeast of RFP. From the reservoir, water is piped to each city's water treatment facilities. Boating, picnicking, and limited overnight camping is permitted at Standley Lake Park.

3.2 OFF-SITE LAND USE

3.2.1 Current

Current land use in the area surrounding RFP is shown in the Jefferson County Land Use Inventory Map (Figure 3-3) and the Boulder County Road Map (Figure 3-4). Table 3-2 is a summary of land use corresponding to the Jefferson County Land Use Map. In general, current land use surrounding RFP includes open space (recreational), agricultural, residential, and commercial/industrial. The northeastern Jefferson County and RFP area is currently one of the most concentrated areas of industrial development in the Denver metropolitan area (Jefferson County 1989).

Current land use in the area relevant to the OU-2 exposure scenarios (immediately southeast of RFP and OU-2) includes all of the uses mentioned above, with the predominant uses appearing to be open space, single-family detached dwellings, and horse-boarding operations. Two small cattle herds (approximately 10 to 20 cattle in each herd) were observed: one to the southeast, where 96th Avenue turns into Alkire and crosses Woman Creek; and one to the east of RFP, between Alkire and Simms Streets and north of 100th Avenue. Industrial facilities within the relevant area, to the south, include the TOSCO laboratory, Great Western Inorganics Plant, and Frontier Forest Products (EG&G 1991a).

3.2.2 Future

Future land use generally follows existing land use patterns. Jefferson County, in its "Northeast Community Profile" (Jefferson County 1989), a socio-economic study of its northeastern area, developed a baseline profile of growth and land use in the area. Using the baseline profile and historic trends, future scenarios were developed. As a result of this study, Jefferson County expects that industrial land uses will continue to dominate the northeastern portion of the county. Along with the increase in industrial development, the county expects income and employment growth to increase dramatically, while household and population growth is expected to increase only moderately. In other words, with industrial growth, employment opportunities are expected to increase; yet, as the land is developed for industry, the availability of land for residential development decreases and, as a result, household and population growth will be limited.

Industrial and commercial development of the area is attractive to businesses and developers for several reasons: (1) the availability of undeveloped and, therefore, lower-cost lands; (2) the lower taxes associated with locating in an unincorporated portion of the county; and (3) the future alignment of W-470, a segment of proposed highway providing access to the area.

The completion of W-470, encircling the entire Denver metropolitan area, is expected to have significant impacts on growth in the area. The highway, in its proposed alignment, will skirt the southern and eastern boundaries of RFP. Commercial growth, particularly light industrial and office development, is expected to occur along the highway (Jefferson County 1989).

Residential development is not as attractive as industrial development of the area for several reasons including the proposed alignment of W-470, the proximity to Jefferson County Airport, and the current industrial nature of the area. The decreased desirability of living near a major highway or an airport, for traffic and noise reasons, is a deterrent to residential development. The proximity of RFP and the general industrial nature of the area also decreases the desirability of housing in the area.

Future land use in the area is the topic of "The North Plains Community Plan" (Jefferson County 1990). The plan is intended to serve as a guide to the county and cities to achieve compatible land use and development decisions, regardless of the jurisdiction in which they are proposed. Representatives of Jefferson County and five cities (Arvada, Broomfield, Golden, Superior, and Westminster), and participants from a variety of interest groups including homeowners, businesses, builders/developers, environmentalists, and special districts, cooperatively developed this plan. The plan identifies the Rocky Flats Plant and the Jefferson County Airport as constraints to future residential development in the area, and recommends office and light industrial development. The plan further identifies the acquisition of lands for open-space uses as a high priority for the area, recommending that large amounts of undeveloped land be provided for this purpose (Jefferson County 1990).

The North Plains Community Development Plan Study Area Summary Map (Figure 3-5) and the Jefferson Center Comprehensive Development Plan (Figure 3-6) show that the predominant future land uses to the south and southeast of RFP will consist of commercial, industrial, and office space. Directly to the east, the zoning and usage are expected to remain open-space and agricultural/vacant. As illustrated in these maps, the areas closest to RFP are planned for industrial, commercial, or office space, with the areas further from RFP designated for residential development. This planning is consistent with the projected residential growth rate of zero in the next 20 years for areas immediately adjacent to the RFP (DOE 1990).

To the north of RFP, in Boulder County, the predominant land uses include open-space, park land, and industrial development, as shown in Figure 3-4. Two areas adjacent to RFP have been annexed by the cities of Broomfield and Superior. These two cities have participated in the Jefferson County cooperative planning process and are planning business, industrial, and mixed land uses for the area (Jefferson County 1990, City of Broomfield 1990, Boulder County 1991).

The above information indicates that current land use in the immediate vicinity of the RFP is primarily commercial/industrial and that such land use will continue into the future. It is therefore likely that the potential for residential development in this area will be impeded by the growth of business and industry that is expected to occur.

3.3 ON-SITE LAND USE

3.3.1 Current

Rocky Flats Plant production and maintenance activities do not occur in the OU-2 area. The 903 Pad portion of OU-2 is capped. A large portion of OU-2 is located within the buffer zone, outside of the security fence and protected area (PA). Current activities in OU-2 consist of environmental investigations and routine security surveillance. RFP is currently planning for decontamination and decommissioning (D&D), which is expected to begin in the near future.

3.3.2 Future

Future plans for RFP activities are discussed in the Nuclear Weapons Complex Reconfiguration Study. The two preferred reconfiguration options in the study include relocation of RFP functions (DOE 1992). Future land-use alternatives are discussed in the "RFP Site-Wide Environmental Impact Statement" (EIS). There are four alternatives that are addressed in that document, including the no-action alternative. These alternatives, which may be subject to change, are summarized below (DOE 1992):

- The no-action alternative involves completing nuclear production upgrades, maintenance of production standby, and compliance with the IAG environmental restoration (ER) commitments.

- Alternative 1 involves nuclear production at reduced levels, compliance with IAG ER commitments, and placement of surplus facilities into safe storage. Due to the recent decision to implement decontamination and decommissioning (D&D) at RFP, this alternative is no longer considered viable.

- Alternative 2 allows nuclear production at up to 1989 levels, increased non-nuclear production, placement of surplus facilities into safe storage, and completion of ER by 2020. Due to the recent decision to implement D&D at RFP, this alternative is no longer considered viable.

- Alternative 3 involves transition to no production of nuclear or non-nuclear components, completion of ER by 2020, D&D of selected facilities, and placement of other facilities into safe storage.

Occupation by private industry is planned for the future use of the on-site production areas at RFP, according to a June 12, 1992, speech by Secretary of Energy James Watkins. Watkins characterized RFP as an attractive site for manufacturers and other businesses (Denver Post, June 13, 1992). Private industry could relocate to existing buildings and use existing equipment at RFP, after necessary decontamination is complete (Boulder Camera June 13, 1992). One organization working to achieve this objective is the Rocky Flats Local Impacts Initiative (RFLII). This group is comprised of representatives from local businesses and government agencies and has been formed to develop a strategy to transform future changes at the RFP into economic, socioeconomic, educational, land use, environmental, and infrastructural advantages. One of this group's goals is to work with the DOE and local economic development agencies to identify and attract businesses to occupy existing buildings at the RFP (RFLII 1992).

When the AEC acquired the undeveloped land surrounding the production area, it established plans to preserve the land as open space (AEC 1972). With the present open space located nearby, it is plausible that the buffer zone and OU-2 area will be preserved as open space. The buffer zone is being considered as a potential ecological preserve or National Environmental Research Park.

> There are at least three reasons why Rocky Flats would make an exceptional environmental research area. First, the site presents an excellent sample of a shortgrass prairie/montane ecotone.... Second, it also provides an almost unique opportunity to conduct environmental research in an area which abuts a major metropolitan area.... Third, ...the site has an abundance of wetlands and would be an excellent outdoor laboratory for a variety of wetland related ecological research (Knight 1992).

Ecological surveys of the buffer zone, performed in compliance with the Threatened and Endangered Species Act, may indicate the presence of several listed species at the RFP. Additional threatened and endangered species surveys are ongoing and may be performed in the future to identify and provide for the protection of any threatened and endangered species at the site, if necessary (EG&G 1992b). Because the buffer zone has not been impacted by commercial development for many years, thus allowing progressive re-establishment of quality native habitats, the future use of this area as an ecological reserve is reasonable. This usage is consistent with DOE policy and plans (DOE 1992). In addition, this type of site use is consistent with the Jefferson County Planning Department's recommendations for the provision of large amounts of undeveloped land in the area (Jefferson County 1990).

Extensive development of the area is unlikely due to the historical use of RFP, the potential for conversion of the buffer zone into an ecological preserve, the limited availability of water, and the steep topography in parts of the drainages. The steep slopes associated with some of the drainages in the area, particularly the Walnut Creek drainage, are not conducive to extensive residential or commercial development. Due to the potential hazards associated with unstable slopes, landslides, and slope failures, Jefferson County emphasizes that development should only occur on slopes with grades of 30 percent or less (Jefferson County 1990). Approximately 25 percent of the land in the eastern portion of the RFP property is at or approaching this grade.

The limited availability of water is also a factor affecting development of the RFP area, as with all of the Denver metropolitan area. The Denver Water Board controls most of the metropolitan water supply and currently provides much of the suburban area's water. The Denver Water Board, however, is under no obligation to supply water to the suburbs, making the future supply questionable (Jefferson County 1989). Due to the quantity of industrial development expected in the area surrounding RFP, it is expected that competition for water will exist. In addition, existing facilities within the RFP are already served by municipal water supplies from the City of Golden, increasing the likelihood that existing structures will be targeted for use by industry and businesses.

In summary, residential development of the area is highly unlikely due to the industrial nature of the RFP site, the general industrial nature of the area, and the proximity of the proposed W-470 corridor and Jefferson County Airport. Future residential land use is inconsistent with current Jefferson County and DOE land-use plans for the area. Future land use generally follows existing land-use patterns and would likely involve industrial/office or open-space uses.

3.4 EVALUATION OF POTENTIAL RECEPTORS

Current and future human population groups on and near the site are potential candidates for evaluation based on their likelihood of exposure to site-related chemicals of concern. EPA guidance does not require an exhaustive assessment of every potential receptor and exposure scenario (EPA 1992). Rather, the highest potential exposures that are reasonably expected to occur (reasonable maximum exposures) should be evaluated, along with an assessment of any associated uncertainty (EPA 1989a).

The current pattern of land use and the likelihood of future land uses are summarized in Table 3-3. The probability that certain land uses will occur in the future is described in terms of increasing credibility, as follows: (1) improbable (unlikely to occur), (2) plausible (conceivable, though not expected), and (3) credible (believable with reasonable grounds). The categorization of land uses presented in Table 3-3 is used to identify potential human receptors for quantitative evaluation in the OU-2 HHRA.

Future on-site uses for agriculture and residential communities are classified as improbable. Future on-site agricultural uses are considered improbable because of:

- Growth pressures on water and land resources from planned off-site development

- Competition with more credible future on-site land uses (e.g., ecological reserve, industrial)

Future on-site residential uses are classified as improbable for multiple reasons, as summarized below:

- Inconsistency with planned off-site industrial and commercial development of the area

- Unattractiveness for residential development because of proximity to current and future industrial uses, including the RFP facilities and the Jefferson County Airport

- Limited water resources for residential development

- Inconsistency with proposed on-site uses for the buffer zone (e.g., ecological reserve, open space) and the current developed areas (e.g., industrial use)

Credible future uses of the RFP on-site include commercial/industrial, recreational uses and the designation of the buffer zone as an ecological reserve. It is expected that the portion of the plant where buildings now exist will continue to be industrial, and the buffer zone will remain undisturbed due to the reasons outlined in Section 3.3. These reasons are:

- Future off-site land use plans point toward industrial and open space usage around the plant

- Private industry is expected to occupy the buildings in the industrial areas on site.

- It would be advantageous to keep the buffer zone surrounding the industrialized on-site area as an ecological preserve/open space due to its unique nature

- Residential development is relatively unattractive because of nearby commercial/industrial development (i.e., the RFP and Jefferson County Airport)

Future use of the area outside the RFP buffer zone (i.e., off site) as an ecological reserve is designated as improbable based on:

- Projected off-site industrial and commercial development of the area

- Unattractiveness of the area as an ecological reserve because the native habitat has been largely disturbed by current agricultural, grazing, and development activities

Future off-site agricultural land use is identified as plausible although such an activity is expected to decrease in the future. It is expected that current agricultural areas will be phased out due to commercial/industrial development expected in this area and associated demands and increasing costs for land and water resources. Future off-site land uses for residential communities, commercial/industrial development, and recreational activities are identified in Table 3-3 as credible exposure scenarios. These land uses are considered credible in the future because they currently exist off site.

3.5 RECEPTORS SELECTED FOR QUANTITATIVE RISK ASSESSMENT

Human populations on and near the site were evaluated to assess their likelihood of exposure to site-related chemicals of concern. EPA guidance does not require an exhaustive assessment of every potential receptor and exposure scenario (EPA 1992). Rather, the highest potential exposures that are reasonably expected to occur (reasonable maximum exposures) should be evaluated, along with an assessment of any associated uncertainty (EPA 1989a). The receptor populations selected for evaluation are those most likely to be exposed and potentially to have the greatest degree of exposure to site-related chemicals.

Receptor populations selected for evaluation in the human health risk assessment at RFP are summarized in Table 3-4 and include current and future off-site residents, future on-site residents, current and future on-site workers, and future on-site ecological researchers. Each of these receptors is described in further detail below. The receptor locations are shown in Figure 3-7. The areas and/or exposure points presented in Figure 3-7 were selected to reflect the most reasonable locations where chemical exposures are expected to occur for each of the receptors. These areas are reasonably consistent with current and future land use at the site and depict locations where each of the respective human receptors are expected to spend the majority of their time. The exposure area for the industrial worker includes all IHSS's for OU-2. The exposure area for the ecological researcher is bounded by Woman and South Walnut Creeks and the entire buffer zone included in OU-2. The areas presented in Figure 3-7 were selected to provide an accurate evaluation of potential chemical intakes in each of the receptors identified. Using collected data and fate and transport modeling at these locations, as appropriate, the exposure point concentrations will be used to quantitatively evaluate chemical intakes for receptors at the selected locations.

3.5.1 Current and Future Residents

The human health risk assessment will evaluate potential health risks for current off-site residents at existing locations, since the public is restricted from access to RFP, and access to OU-2 is generally limited to certain on-site workers. Present levels of security at the RFP include secure fencing, frequent armed security patrols, and modern electronic security and surveillance systems. Fencing is posted to warn potential intruders that they are trespassing on federal property and,if caught, will be arrested. Plant security personnel report that there have been no incidents of trespassing in the buffer zone in the past seven years. Thus, even if trespassing were to occur at the RFP, it is highly unlikely that such events would occur repeatedly for the same individual.

This scenario will evaluate the reasonable maximum risk to the residents both now and in the future. Based on the future industrial/commercial land-use plans for the area, hypothetical future residents will be evaluated off-site in the vicinity of existing residential areas due to the existence of current residences. These future residents will be quantitatively evaluated at the site boundary, where Woman and Walnut Creeks leave the RFP site. These locations will correspond to the most reasonable locations for maximum exposures due to their proximity to the site, the direction of prevailing winds, and the proximity of surface water bodies originating on site. Since residents are likely to spend the greatest amount of time at or near their home, the residential scenario will represent the maximum frequency and duration of exposure that is reasonably expected to occur. Although on-site residences are not consistent with future land-use plans, a hypothetical future on-site resident exposure scenario will be evaluated in the health risk assessment. The future on-site resident will be assumed to live within the OU-2 area boundary.

3.5.2 Current and Future On-Site Workers

Although the health and safety of on-site workers is monitored under the health and safety plan, a current on-site worker exposure scenario will be evaluated in the human health risk assessment. The current RFP workers who spend the greatest amount of time in OU-2 are plant security personnel. Guards conduct routine patrols within OU-2.

The human health risk assessment will evaluate current and future on-site workers. The health and safety of on-site workers is presently monitored under a comprehensive health and safety program at RFP. Health and safety (H&S) activities at RFP are directed by the Associate General Manager for Support Operations and supported by several divisions including Radiological Operations, Occupational Safety, Health and Safety Area Engineering, Industrial Hygiene, Radiological Engineering, and Occupational Health (EG&G 1990). An organizational chart is provided in Figure 3-8. For environmental restoration work at RFP, EG&G (Rocky Flats Plant) and DOE have adopted the Federal Occupational Safety and Health Administration's (OSHA) standards for hazardous-waste site workers (EG&G 1990). EG&G has superseded some of the OSHA standards with more stringent policies established by EG&G, DOE, or other governmental agencies (EG&G 1990).

At RFP, H&S programs are written for everyday activities as well as specific projects. All subcontractors to EG&G must prepare their own site/project-specific H&S plans, and they must require and enforce standards that are at least as stringent as EG&G's requirements (EG&G 1990). Several programs exist at RFP to support the H&S plans and programs, including radiation protection, emergency response, occupational safety, vehicular and pedestrian safety, fire protection, and contractor safety (EG&G 1992c). The written programs contain the requirements and procedures to be followed to ensure a work environment that is free from exposure to chemical, physical, and biological hazards (EG&G 1992c). Additionally, responsibility for all aspects of compliance with the programs and plans is established, and an audit program is in place to evaluate whether compliance is in effect. RFP personnel are trained in personal hygiene and safety, use of protective clothing, and emergency response procedures. The health and safety of current workers at RFP is thoroughly monitored with required baseline, annual, and exit physical examinations. The exposure of these workers to chemicals of concern is controlled and limited by monitoring to acceptable levels and is ensured by reporting requirements.

A future on-site worker, not protected by a similar health and safety program (i.e., no-action) will also be quantitatively evaluated in the health risk assessment. This worker is assumed to be unprotected and untrained in health and safety matters. Based on the future industrial development plans for the area, the future on-site workers are assumed to be an industrial or office worker, and a construction worker. The setting for the industrial or office worker is likely to have extensive paved areas and well-maintained landscaping. The location of this receptor is shown in Figure 3-7. The location designated for on-site workers represents a reasonable exposure area for that receptor. The future on-site construction worker is assumed to have direct contact with soil during excavation activities associated with the construction of future commercial buildings on site.

3.5.3 Future On-Site Ecological Researcher

Since the future use of the on-site, non-production areas at RFP will most likely involve an open-space/ecological reserve scenario, this scenario will be evaluated for the area outside of the OU-2 IHSSs. The receptors in an open-space scenario would include day hikers and a research biologist/ecologist conducting area studies. Of these two potential receptors, the research biologist is likely to spend more time at the RFP site and come in close contact with the soils, plants, and surface water, as specimens are studied. Field work may involve kneeling or lying on bare ground or vegetation, and contacting site soils, sediments and surface water. The day hiker would most likely spend less time at the site and come in less contact with the site's soils and surface water. Therefore, the most reasonable receptor in this setting is the hypothetical future ecological researcher. The area applicable to this receptor is shown in Figure 3-7 and includes the areas between Woman and Walnut Creeks. This receptor will be quantitatively evaluated in the risk assessment.

TABLE 3-1

CURRENT AND PROJECTED POPULATIONS IN THE OU-2 EXPOSURE ASSESSMENT AREA

	Year 1989/2010					
Sector	D	E	F	G	H	I
1	0/0	0/0	0/0	0/0	0/0	0/0
2	0/0	0/0	0/0	0/0	0/0	0/0
3	0/0	0/0	0/0	17/17	0/0	7/7
4	0/14	283/644	46/142	50/50	215/1007	3/3
5	25/25	3671/5009	477/601	578/1879	2355/10186	469/2124

Source: DOE 1990. "1989 Population, Economic, and Land Use Data for Rocky Flats Plant."

TABLE 3-2

ROCKY FLATS PLANT
OU-2
CURRENT SURROUNDING LAND USE IN JEFFERSON COUNTY

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
22009			
44001	Vacant	A-2	Vacant
44002			
44003	Vacant	I-1	Industrial
44004	Vacant	A-2	Vacant
44005			
44006	Vacant	I-3	Industrial
44007	Vacant	A-2	Vacant
45001			
45002	Walnut Creek Unit 1	P-D	Single Family - Detached
45002	Walnut Creek Unit 1	P-D	Retail
45003	Vacant	A-2	Vacant
45004	Single Family - Detached	A-2	Single Family - Detached
45005	Single Family - Detached	A-2	Vacant
45006	Water	A-2	Water
45007	Single Family - Detached	A-2	Single Family - Detached
45007	SF-D	A-2	Farm/Ranching
46005	Vacant	A-2	Single Family - Detached
46006	Triple C Quarter Horses	A-2	Retail
46007	Horse Barn-Boarding & Breeding	A-2	Retail

TABLE 3-2
(Continued)

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
46008	Single Family - Detached	A-1	Single Family - Detached
46009	Single Family - Detached	SR-2	Single Family - Detached
46011	Mountain View Tech Center	P-D	Industrial
46012	Jefcope	P-D	Industrial
46017	Water	A-2	Water
46019	Single Family - Detached	A-2	Single Family - Detached
47036	Vacant	SR-2	Single Family - Detached
47040			
71001	Rocky Flats	A-2	Industrial
72001	Vacant	I-2	Industrial
72002	Vacant	A-2	Vacant
72003	Single Family - Detached	A-2	Single Family - Detached
72004	Vacant	I-2	Vacant
72004	Vacant	I-2	Industrial
72005	Tosco Flg 1	I-2	Industrial
72006	Rocky Flats Ind Park Flg 2	I-2	Industrial
72007	Rocky Flats Ind District Flg 1	I-2	Industrial
72008	Water Tank Ralston Val Stn 2	I-2	Utilities
72009	Vacant - Rocky Flats	A-2	Industrial
72010	Vacant	I-2	Industrial
72011	Northwest Industrial	I-2	Industrial

TABLE 3-2
(Continued)

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
72012	Vacant	A-2	Vacant
72013			
73001	Vacant	A-2	Vacant
73005	Wheat Ridge Gardens	A-2	Vacant
73019	Vacant	A-1	Vacant
73020	Single Family - Detached	SR-2	Single Family - Detached
73021	Vacant	RC	Office/Retail
73022	Westminster Gardens	A-2	Single Family - Detached
99001	Great Western Aggregate Quarry	I-1	Industrial
99005	Sawmill Operation	I-2	Industrial
99006	Great Western Aggregates	I-2	Industrial
99007	Vacant	I-2	Industrial
99008	Colorado Brick Comp Clay Mine	M-C	Mining
99009	Vacant	I-2	Industrial
100001	Rock Creek Ind Park Vacant	P-D	Industrial
100002	Vacant	I-1	Industrial
100003	Rocky Flats - Vacant	I-1	Industrial
100004	Rocky Flats - Clay Extraction	M-C	Industrial
100005	Rocky Flats - Vacant	I-2	Industrial
100006	Electric Substation	M-C	Utilities
100006	Gravel Mine	M-C	Industrial
101001	Vacant	A-2	Vacant

TABLE 3-2
(Concluded)

Parcel #	Current Use/ Project Name	Zoning[1]	Land Use Type
101002	Vacant	M-C	Industrial
101003	Vacant	I-2	Industrial
101004	Mine and Water	I-2	Industrial
101005	Northwest Industrial	I-2	Industrial
101006	Vacant	M-C	Industrial
101007	Sanitary Landfill and Gravel	P-DA	Industrial
101008	Rocky Flats Lake	M-C	Water

[1] Zoning Abbreviations are as follows:

A-1 Agricultural 1
A-2 Agricultural 2
I-1 Industrial 1
I-2 Industrial 2
I-3 Industrial 3
P-D Planned Development
SR-2 Suburban Residential 2
RC Restricted Commercial
P-DA Planned Development Amended
Source: Jefferson County

TABLE 3-3

SUMMARY OF CURRENT AND FUTURE LAND USES[a,b,c]

Land Use Category	Current		Future	
	Off Site	On Site	Off Site	On Site
Residential	Yes	No	Credible	Improbable
Commercial/Industrial	Yes	Yes	Credible	Credible[d]
Recreational	Yes	No	Credible	Credible[e]
Ecological Reserve	No	No	Improbable	Credible[e]
Agricultural	Yes	No	Plausible	Improbable

[a]Credible is used to indicate scenarios that may reasonably occur.
[b]Plausible is used to indicate scenarios that are conceivable, though not expected.
[c]Improbable is used to indicate scenarios that are unlikely to occur.
[d]Expected in the currently developed area of the plant site.
[e]Expected in the buffer zone.

TABLE 3-4

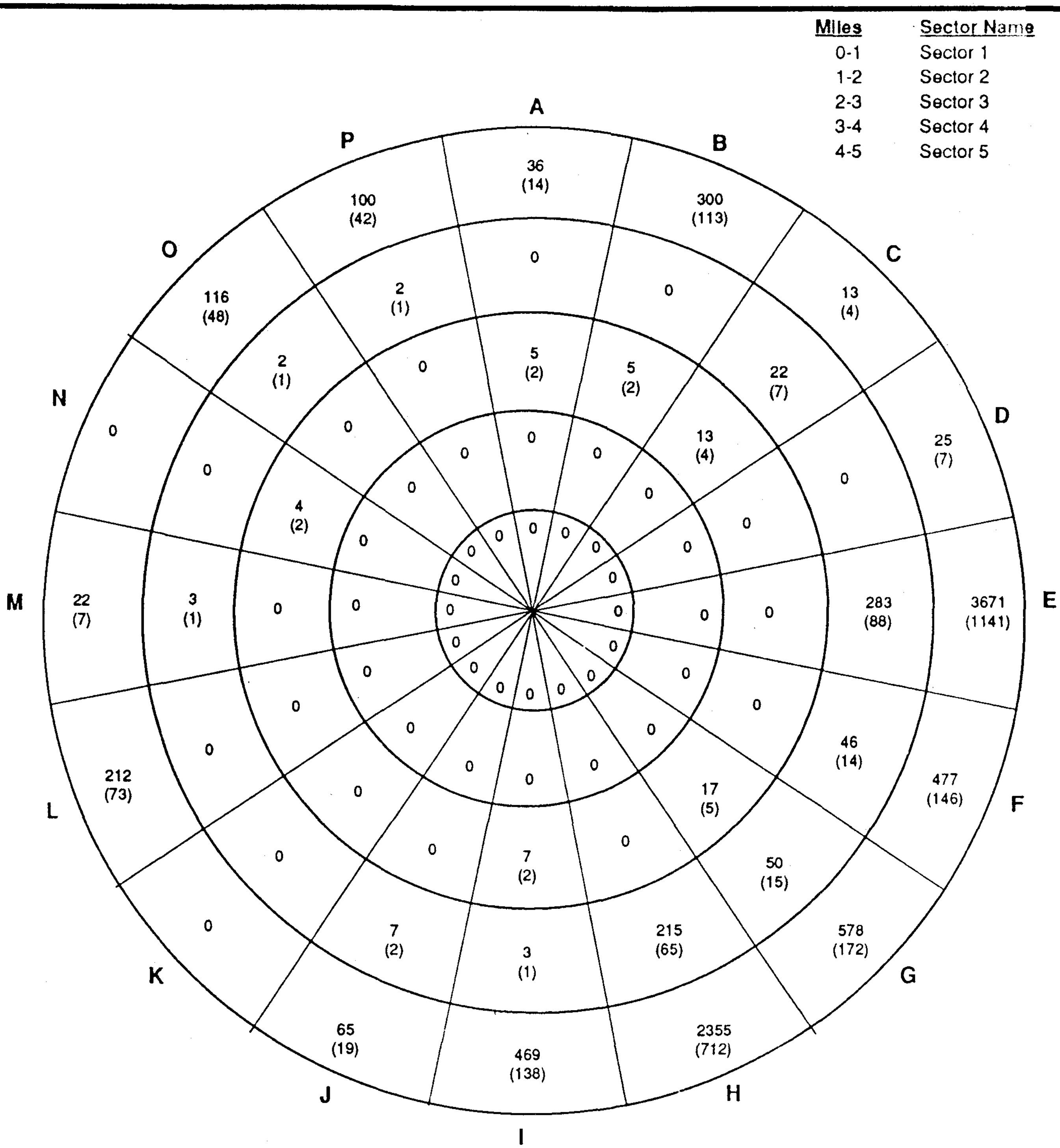
ROCKY FLATS PLANT
OU-2
POTENTIALLY EXPOSED RECEPTORS TO BE QUANTITATIVELY EVALUATED

Current Scenario	Future Scenario
Off-site resident	On-site worker (office and construction)
On-site worker	On-site ecological researcher
	Hypothetical off-site resident (1)
	Hypothetical on-site resident (2)

(1) A future off-site hypothetical resident will be quantitatively evaluated at the following locations:

   (a) Point at which Walnut Creek intersects the eastern Rocky Flats Plant property boundary
   (b) Point at which Woman Creek intersects the eastern Rocky Flats Plant property boundary

(2) A future on-site hypothetical resident will be quantitatively evaluated within the OU-2 area.



SOURCE: DOE, 1990.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

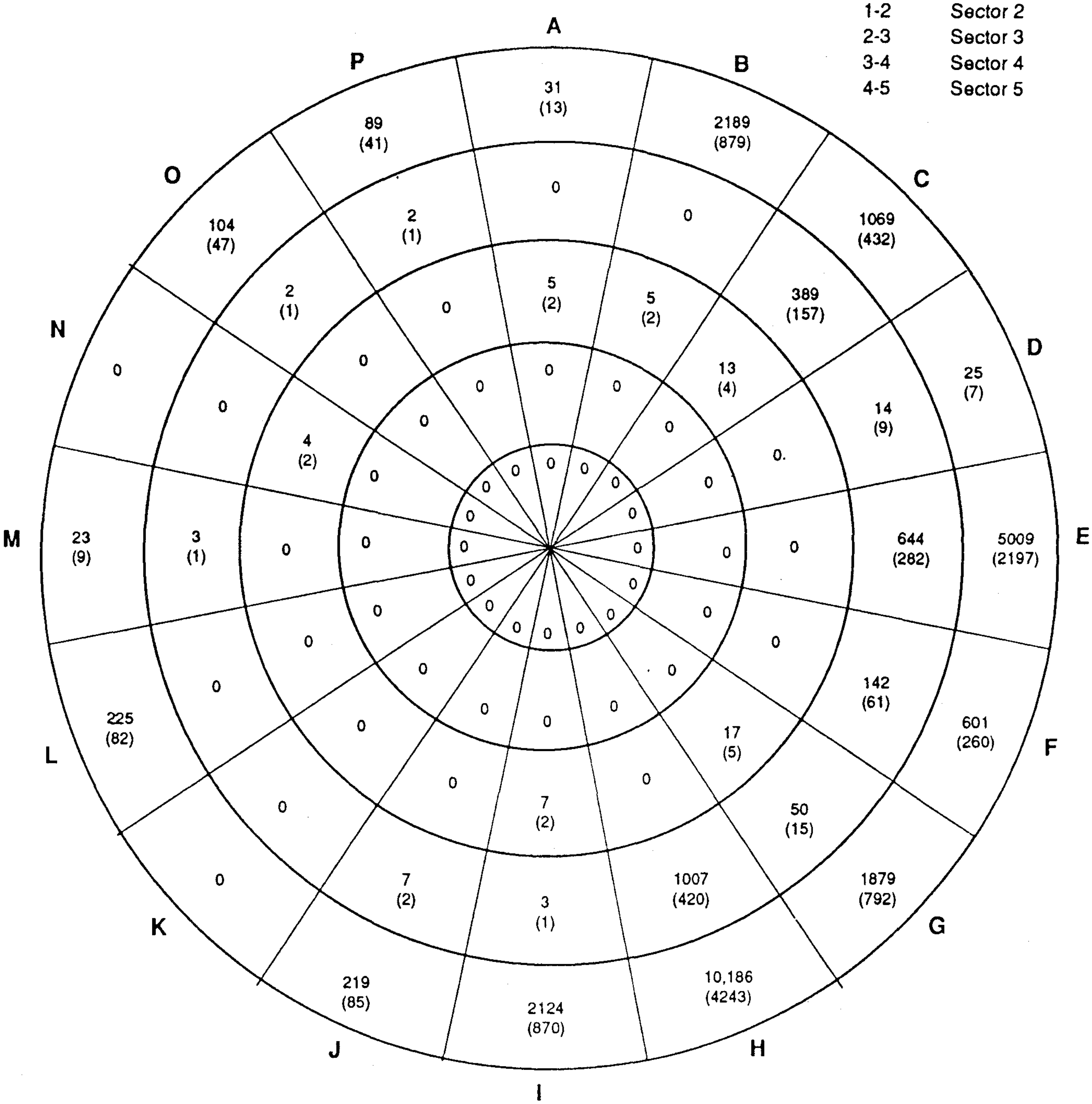
OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

1989 POPULATION AND
(HOUSEHOLDS) SECTORS 1–5

FIG. NO. 3–1 JUNE, 1992

23047031

Miles	Sector Name
0-1	Sector 1
1-2	Sector 2
2-3	Sector 3
3-4	Sector 4
4-5	Sector 5



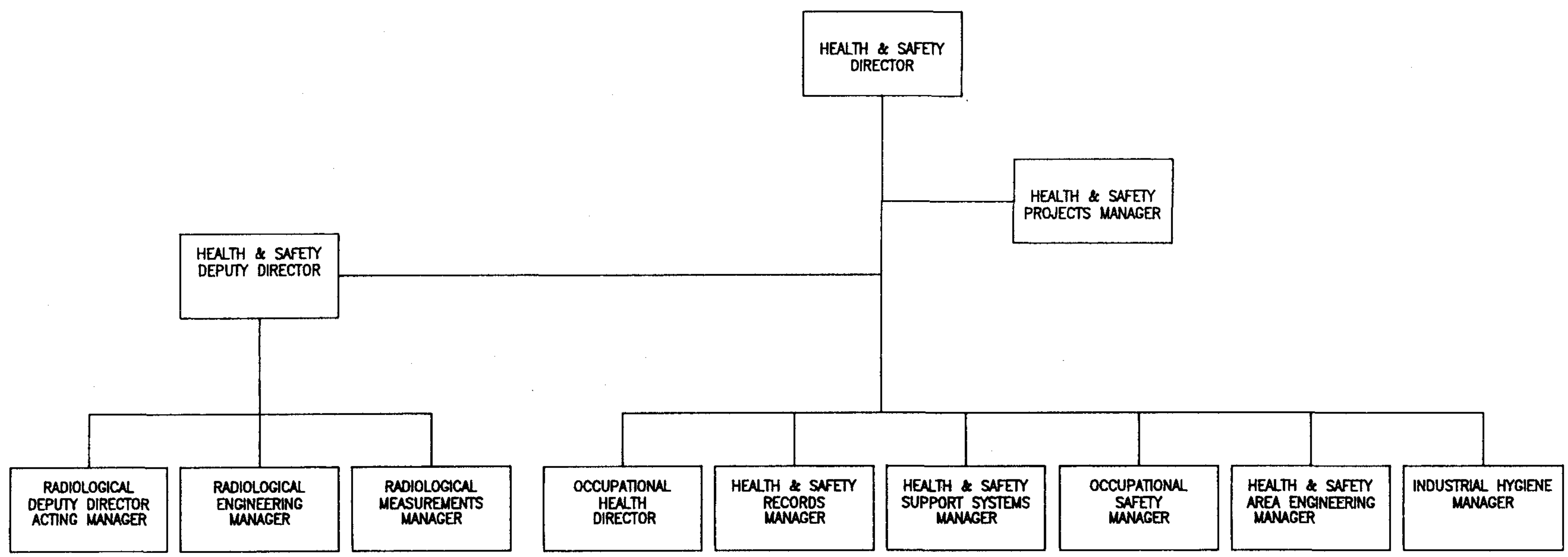
SOURCE: DOE, 1990.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

2010 POPULATION AND (HOUSEHOLDS) SECTORS 1–5

FIG. NO. 3–2 JUNE, 1992



SOURCE: EG&G, 1990.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

EG&G ROCKY FLATS
HEALTH & SAFETY ORGANIZATION

FIG. NO. 3-8 JUNE, 1992

23047CHT

4.0
EXPOSURE PATHWAYS

This section discusses the potential release and transport of chemicals from OU-2 and identifies exposure pathways by which the receptor populations identified in Section 3.0 may be potentially exposed to site chemicals.

An exposure pathway describes a specific environmental pathway by which an individual can be exposed to chemical constituents present at or originating from a site. An exposure pathway includes five necessary elements:

- A source of chemicals
- A mechanism of chemical release
- An environmental transport medium
- An exposure point
- A human intake route

Each one of these five elements must be present for an exposure pathway to be complete. An incomplete pathway means that no human exposure can occur. Only potentially complete and relevant pathways will be addressed in the human health risk assessment for OU-2. An exposure pathway is considered to be potentially complete and relevant if there are potential chemical release and transport mechanisms, and identified receptors for that exposure pathway.

4.1 CHEMICAL RELEASE SOURCES AND TRANSPORT MEDIA

The identified site sources at OU-2 are the 903 Pad, Mound, and East Trenches areas. The BRA will evaluate contaminated soil at these OU-2 sites as the primary source of chemical release. A description of historical activities conducted at OU-2 was provided in Section 2.1. Environmental media that may transport chemicals of concern from OU-2 to exposure points are described in the conceptual site model described in Section 4.5.

4.2 POTENTIALLY EXPOSED RECEPTOR POPULATIONS

Potentially exposed receptor populations selected for quantitative assessment in the baseline human health risk assessment were characterized in Section 3.0. The following receptors were selected:

- Current off-site resident
- Current on-site worker
- Future on-site worker
- Future on-site ecological researcher
- Future off-site resident
- Future on-site resident

Current land-use conditions should consider that a RFP surface water management plan is in effect. This program includes surface water treatment, as necessary, prior to discharge off site. However, the future land use scenarios assume no action takes place at OU-2 (i.e., no surface water management plan is in place and no surface water treatment occurs) and estimates exposures for future receptor populations under this condition. The potential contribution of site-related chemical concentrations from the seeps along the Walnut and Woman Creek drainages will be included in the groundwater modeling of exposure point concentrations for potential surface water exposure pathways.

4.3 EXPOSURE POINTS

An exposure point is a specific location where human receptors can come in contact with site-related chemicals. Exposure points are selected so that reasonable maximum exposures will be quantitatively evaluated. Evaluation of receptor risks at these exposure points will bound the risks for receptors at other exposure points not selected for quantitative evaluation. The following exposure points were selected for reasonable maximum estimates of risk. These locations are shown in Figure 3-7.

Current Scenario

- Residential receptor. Nearest residence to RFP (located at the southeast corner of the RFP property boundary) and nearest residence to RFP which is in the predominant wind direction.

- Occupational receptor. On-site, within the OU-2 area.

Future Scenario

- Occupational receptor. On site, within the OU-2 industrial complex.
- Ecological researcher. On site, within RFP buffer zone east of OU-2, bounded by Woman and South Walnut Creeks.
- Residential receptors. Hypothetical off-site residences at the following locations:

  (1) Point at which South Walnut Creek intersects the eastern Rocky Flats Plant property boundary
  (2) Point at which Woman Creek intersects the eastern Rocky Flats Plant property boundary

  Hypothetical on-site residences within the OU-2 area.

4.4 HUMAN UPTAKE MECHANISMS

A human uptake mechanism is the route by which a chemical is internally absorbed by the receptor. There are four basic human uptake mechanisms: dermal absorption, inhalation, ingestion, and, if radionuclides are present, external irradiation. Exposure pathways by which these mechanisms may occur include inhalation of VOCs and airborne particulates, soil ingestion, surface and groundwater ingestion, and dermal contact with soil or surface water. These uptake mechanisms are described further in Section 5.0.

Dermal absorption of metals from contact with soil is not considered a significant uptake route by EPA. In the Preliminary Risk Assessment for Leadville, Colorado, EPA Region VIII states:

> Metals bind strongly to soil greatly reducing their bioavailability. Through complex processes, most metals form strong, stable bonds with other soil constituents that reduce the available concentration of a dissolved metal. In addition, due to polarity and solubility, metals are not absorbed well across the skin. Therefore, relative to other exposure routes, dermal absorption is expected to be inconsequential (EPA 1991a).

Likewise, because metals are not highly soluble in water and tend to be bound to soil particles or sediments, dermal uptake of particulate-bound metals in surface water is judged to be a negligible exposure pathway. However, the soluble fraction of chemicals of concern, including metals, in surface water will be quantitatively evaluated. For radionuclides, EPA guidance states that "dermal uptake is generally not an important route of uptake for radionuclides, which have small dermal permeability constants" (EPA 1989a). Dermal contact with soil will only be assessed quantitatively if sampling results from the OU-2 Phase II investigation demonstrate the presence of organic chemicals of concern in surface soil samples at concentrations exceeding background levels.

4.5 CONCEPTUAL SITE MODEL

Information concerning waste sources, waste constituent release and transport mechanisms, and locations of potentially exposed receptors is used in this section to develop a conceptual understanding of the site in terms of potential human exposure pathways. Figure 4-1 shows a conceptual site model (CSM) of potential human exposure pathways for OU-2.

The CSM is a schematic representation of the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors. The purpose of the CSM is to provide a framework for problem definition, to identify exposure pathways that may result in human health risks, to aid in identifying data gaps, and to aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways.

Chemical release mechanisms, environmental transport media, and potential human intake routes to the contaminated site soil were identified for each potentially exposed receptor and are discussed in Section 4.5.2.

In the CSM, potentially complete and significant exposure pathways are designated by an "S." Potentially complete and relatively insignificant exposure pathways are designated by an "I." Both potentially complete and relatively significant exposure pathways and relatively insignificant exposure pathways will be quantitatively addressed in the risk assessment. Quantitatively addressing potentially complete and relatively insignificant exposure pathways will provide for risk estimates that do not underestimate actual risks. Negligible or incomplete exposure pathways are designated by an "N" and are not addressed in the risk assessment. In the following discussion and in the CSM, potentially complete dermal exposure pathways are designated as insignificant and will only be assessed quantitatively if results from the Phase II site investigation demonstrate the presence of organic chemicals or soluble metals of concern, as previously discussed in Section 4.4.

4.5.1 Site-Wide Incomplete Exposure Pathways

The CSM indicates that the following five OU-2 exposure pathways are negligible or incomplete for all receptors. These incomplete pathways will not be quantitatively addressed in the risk assessment.

- Ingestion of fish caught from Woman or Walnut Creeks, and ingestion of livestock watered by these creeks are incomplete exposure pathways for all receptors. Walnut and Woman Creeks are both intermittent creeks. High-flow periods for these creeks generally occur from March to June. The amount of flow varies significantly from no-flow in dry years to approximately four times the predicted annual flow (Advanced Sciences, Inc. 1990).

Due to their intermittent nature, the creeks do not support significant numbers of fish. The only fish observed have been minnows. However, it is possible for fish that reside in on-site ponds to migrate from these ponds along Woman Creek to Standley Reservoir or along South Walnut Creek during high-flow periods (WWE 1991; WCC 1992). However, because of the creeks' intermittent nature, subsistence fishing is unlikely. Therefore, ingestion of fish is a negligible exposure pathway for both current and future residential receptors.

Because plant growth over the creeks does not allow ready access to the creek and because the intermittent creek flow does not support consistent livestock watering, ingestion of livestock is a negligible pathway for both current and future residential receptors.

The current and future on-site workers are unlikely to raise cattle or catch fish on site since he/she is expected to work the entire time while on site. Therefore, this pathway is considered negligible for these receptors. Ingestion of animals or fish in the future scenario by the ecological researcher is an incomplete pathway because it is unlikely that the researcher will ingest animal or fish specimens collected for research.

- Inhalation of chemicals that have volatilized from site soils or groundwater to outdoor air are negligible pathways for all receptors because volatile chemicals in surface soils have already volatilized, and volatile chemicals released from groundwater are expected to be significantly retarded through the vadose zone and diluted in the ambient air.

- Based on current information, significant concentrations of volatile organics and metals have not been detected in the Lower Hydrostratigraphic Unit (LHSU). Therefore, ingestion of, or dermal contact with, groundwater from the LHSU is an incomplete pathway for all receptors.

4.5.2 Potentially Complete Exposure Pathways

Exposure pathways that result in potential exposure to identified receptors are discussed below.

4.5.2.1 Current Off-Site Resident

The CSM for the current off-site resident indicates that storm water runoff, volatilization, wind suspension, infiltration and percolation, direct contact, plant uptake, and radioactive decay are the potential chemical release mechanisms from contaminated site soils to the environment. Of these release mechanisms, only the exposure routes associated with wind suspension are potentially complete for the current off-site resident, as detailed in the discussion below. Direct contact with site soils, ingestion of vegetables and fruits/plants grown in on-site soils, and on-site external irradiation from radioactive decay of site soils are also potential release mechanisms, but are eliminated as exposure pathways to this receptor because site access is restricted. Similarly, no groundwater wells (other than monitoring wells) are located on-site and, therefore, no direct consumption of groundwater occurs on-site for residents or workers. Therefore, current off-site residents could not directly come into contact with or come close to contaminated soils on site.

Groundwater in the Upper Hydrostratigraphic Unit (UHSU) at OU-2 may either discharge to surface water in the Walnut Creek basin or is lost via evaporation from seeps and springs. (Annual free-water evaporation in this region is greater than the amount of annual precipitation.) Chemicals potentially discharged from groundwater to surface water or potentially released from site soils to surface water via storm water runoff may be transported to surface water and/or sediments in Walnut or Woman Creek. Groundwater and surface water runoff from OU-2 that reaches the Walnut Creek drainage is captured on site by the B-series ponds and treated in accordance with RFP's surface water management plan (see Section 2.5.3). A smaller proportion of UHSU groundwater and surface water runoff from OU-2 flows south to the Woman Creek basin or is captured by the south interceptor ditch (SID). The SID surface water flows to the C-2 Pond. Surface water in the C-2 Pond and in Woman Creek is sampled in accordance with the RFP's surface water management plan, which has received EPA approval. Under this monitoring program, surface water is monitored and discharged at concentrations that meet applicable federal and state surface water requirements. Therefore, incidental ingestion of and dermal contact with surface water and/or sediments in the creeks are considered incomplete exposure pathways for the current off-site resident.

Groundwater in the UHSU is hydraulically disconnected from the lower-confined aquifer by an impermeable claystone ranging from 15 to 30 meters (50 to 100 feet) in thickness (see Section 2.0). Thus, potential exposure pathways (including inhalation of indoor VOCs that may volatilize from groundwater) associated with domestic wells, located west of Standley Lake and along the Woman Creek drainage, are considered incomplete. There are no domestic wells located west of Great Western Reservoir in the Walnut Creek drainage.

Chemicals bound to soil that are released via wind as particulate matter represent potential inhalation, oral, dermal, and external irradiation exposure pathways. Current off-site residents may be directly exposed to airborne particulate matter via inhalation. For the purpose of the HHRA, it will be assumed that indoor air particulate concentrations are equal to outdoor air particulate concentrations. Therefore, for all potentially exposed receptor populations, potential risks from inhalation of indoor particulates will be accounted for by the quantitative evaluation of potential risks from inhalation of outdoor particulates. Homegrown garden vegetables, contaminated by deposition of airborne particulates from the site, represent a potentially complete ingestion pathway. Likewise, soil that is contaminated by particulate deposition represents potentially complete oral (relatively insignificant) and dermal (relatively insignificant) exposure pathways for this receptor.

External irradiation exposures to off-site residents resulting from deposition of radionuclides via airborne particulate are expected to be an incomplete pathway since relatively low concentrations of radionuclides in off-site residential soils due to fugitive dust deposition are expected. In addition, the primary radionuclides of concern at the RFP, plutonium and americium, do not have highly penetrating radiation associated with them.

As shown in the CSM, plant uptake of contaminants deposited as windblown particulates on soil may potentially occur. However, this uptake pathway is considered incomplete for the following reasons:

- As mentioned in Section 4.4, metals bind tightly to soil, thus greatly reducing their bioavailability to plants (EPA 1991a).

- Chemical concentrations from particulates deposited on residential soil will be significantly diluted by tilling.

For these reasons, chemical concentrations in garden vegetables, due to surface deposition of chemicals onto plants, are expected to be greater than chemicals taken up by vegetables from the soil contaminated by particulate deposition. It is expected that direct contact exposures to surface soil (dermal absorption and ingestion) will greatly exceed chemical intakes associated with plant uptake and subsequent ingestion. The uptake of chemicals by vegetables from off-site soil contaminated by particulate deposition pathway is, therefore, considered negligible. Therefore, current residential intake of vegetables will only be evaluated for surface deposition of particulates on plants.

In summary, potentially complete human exposure pathways for the current off-site resident are:

- Inhalation of airborne particulates
- Soil ingestion (following deposition of particulates on residential soil)
- Dermal contact with soil (following airborne deposition of particulates)
- Ingestion of vegetables (following surface deposition of particulates)

4.5.2.2 <u>Current On-Site Worker</u>

The CSM for the current on-site worker indicates that storm water runoff, volatilization, wind suspension, infiltration and percolation, direct contact, direct uptake by vegetables and fruits/plants, and radioactive decay are the potential chemical release mechanisms from contaminated site soils to the environment. Of these release mechanisms, only wind resuspension, direct contact, and external irradiation result in associated potential exposure routes for the future on-site worker. For the future on-site construction worker, volatization, wind resuspension, direct contact, and radioactive decay result in associated potential exposures.

If released via storm water runoff, site chemicals may be transported to surface water and/or sediments. Surface water is present on site in Woman and Walnut Creeks and in surface water treatment ponds, which are all located in the RFP buffer zone (see Section 2.5). Incidental ingestion of and dermal contact with surface water and suspended sediments are incomplete exposure pathways for current on-site workers because they would have no reason to come into contact with surface water. If they were to come in contact with the water, they would be monitored under a strict Health and Safety program.

Semivolatile organic and inorganic chemicals bound to soil that are released via wind as particulate matter represent potential inhalation, oral, or dermal exposure pathways. Current on-site workers may be directly exposed to airborne particulate matter via inhalation. Direct contact with soil that has been contaminated through the deposition of airborne particulates will be evaluated via direct measurement of chemicals in surface soil on site. This pathway is accounted for by the Direct Contact release mechanism in Figure 4-1. Ingestion of contaminated vegetables is an incomplete pathway because gardening is not expected in an occupational setting.

The pathway of exposure to surface water that is discharged from UHSU groundwater is incomplete because the current on-site worker is expected to patrol in the industrial complex area and is not expected to come into contact with surface water at the Woman or Walnut Creek drainages. Drinking water for on-site workers is supplied by a municipal water supply that does not tap aquifers at the RFP. This situation is expected to continue into the future.

Direct contact with soils represents potentially complete ingestion (significant) and dermal contact (insignificant) exposure pathways for current workers at the site. External irradiation from decay of radioactive materials in contaminated site surface soils is also a potentially complete (insignificant) exposure pathway due to the potential existence of contaminants in surficial soils and relatively high rate of intake associated with this waste. Exposure to radioactive materials via inhalation, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for this receptor.

Currently, no offices or other permanent structures are located on OU-2. Thus, the inhalation of VOCs indoors is an incomplete exposure pathway.

In summary, potentially complete human exposure pathways for the current on-site workers are:

- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil
- External irradiation

4.5.2.3 Future On-Site Workers (Office and Construction)

The CSM for the future on-site workers indicates that storm water runoff, volatilization, wind suspension, infiltration and percolation, direct contact, direct uptake by vegetables and fruits/plants, and radioactive decay are the potential chemical release mechanisms from contaminated site soils to the environment. Of these release mechanisms, all except storm water runoff result in associated potential exposure routes for the future on-site office worker. For the future on-site construction worker, volatization, wind resuspension, direct contact, and radioactive decay result in associated potential exposures.

If released via storm water runoff, site chemicals may be transported to surface water and/or sediments. Surface water is present on site in Woman and Walnut Creeks and in surface water treatment ponds, which are all located in the RFP buffer zone (see Section 2.5). Incidental ingestion of and dermal contact with surface water and suspended sediments are incomplete exposure pathways for both types of future on-site workers because the office and construction workers would work in the industrial complex. Therefore, future on-site workers would have no reason to come into contact with surface water.

Chemicals that volatilize from groundwater and/or site soils and are released to indoor air represent a potentially complete inhalation pathway for the future on-site office worker. Although VOCs have not been detected in outdoor field measurements, it is possible for VOCs to accumulate indoors even though they may be dispersed and significantly diluted outdoors. Semivolatile organic and inorganic chemicals bound to soil, that are released via wind as particulate matter, represent potential inhalation, oral, or dermal exposure pathways.

Both types of future on-site workers may be directly exposed to airborne particulate matter via inhalation. Potential oral and dermal exposures via this pathway will be evaluated via the Direct Contact release mechanism (Figure 4-1). Ingestion of contaminated vegetables is an incomplete pathway because gardening is not expected in an occupational setting.

Volatilization of VOCs from alluvial groundwater to indoor air represents a potentially complete (significant) inhalation exposure pathway for the future on-site office worker because, although VOCs may have already volatilized and dispersed outdoors, they have the potential to accumulate indoors.

The pathway of exposure to surface water that is discharged from UHSU groundwater is incomplete because both types of on-site workers are expected to remain in the industrial complex area and are not expected to come into contact with surface water at the Woman or Walnut Creek drainages.

Direct contact with soils represents potentially complete ingestion (significant for the office worker and insignificant for the construction worker) and dermal contact (insignificant for both) exposure pathways for future workers at the site. External irradiation from decay of radioactive materials in contaminated site surface soils is also a potentially complete (insignificant) exposure pathway. Exposure to radioactive materials via ingestion, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for this receptor.

In summary, potentially complete human exposure pathways for the future on-site office and construction workers are:

- Inhalation of VOCs in indoor air (office worker only)
- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil
- External irradiation

4.5.2.4 Future On-Site Ecological Researcher

The CSM for the future on-site ecological researcher indicates that storm water runoff, volatilization, wind suspension, infiltration and percolation, direct contact, and radioactive decay are the potential chemical release mechanisms from contaminated site soils to the environment. Except for volatilization, all of these release mechanisms have associated exposure routes that are potentially complete for the future ecological researcher.

If released via storm water runoff or transported via groundwater, site chemicals may be released to surface water and/or sediments. Incidental ingestion of surface water and sediments is a potentially complete and significant exposure pathway for the ecological researcher who may be wading in Walnut or Woman Creek. Suspended particulates in surface water resulting from the disturbance of sediment may be ingested and will be accounted for in the surface water ingestion exposure pathway. Dermal contact with the surface water and sediments is a relatively insignificant but potentially complete exposure pathway for this receptor. Soluble chemicals in sediments may be released to surface water and dermally absorbed, and will be accounted for in the dermal contact with surface water exposure pathway.

Chemicals that volatilize from site soils or groundwater may be released to indoor air and outdoor air. Inhalation of VOCs in outdoor air is considered an incomplete exposure pathway because volatile chemicals in surface soils have already volatilized and volatile chemicals in groundwater are expected to be significantly retarded through the vadose zone and diluted in the ambient air. Inhalation of indoor air is also an incomplete exposure pathway because the researcher will spend his time outdoors in the buffer zone while on site.

Chemicals bound to soil that are released via wind as particulate matter represent potential inhalation, oral, and dermal exposure pathways. Future on-site ecological researchers may be directly exposed to airborne particulate matter via inhalation, the ingestion of chemical-containing soil, or dermal absorption of chemicals in soil. These pathways will be quantitatively evaluated as described previously for on-site workers. Direct contact with surface soils represents potentially complete oral and dermal absorption exposure pathways for future ecological researchers. Ingestion of contaminated plants is an incomplete pathway because it is unlikely that the ecological researcher will ingest plant specimens collected for research.

External irradiation from decay of radioactive materials in contaminated site surface soils is also a potentially complete exposure pathway. Exposure to radioactive chemicals via ingestion, oral, or dermal uptake routes other than external irradiation is accounted for in the other potentially complete exposure pathways described for this receptor.

In summary, potentially complete human exposure pathways for chemicals released from contaminated site soils for the future ecological researcher are:

- Surface water/suspended sediment ingestion
- Dermal contact with surface water/suspended sediment
- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil
- External irradiation

4.5.2.5 Future Off-Site Resident

The CSM for the future off-site resident indicates that storm water runoff, volatilization, wind suspension, and infiltration and percolation are the potential chemical release mechanisms from contaminated site soils to the environment. Of these primary release mechanisms, all except volatilization provide potential exposure routes to the future off-site resident.

Chemicals that are discharged from groundwater to surface water or that are released from site soils to surface water via storm water runoff may be transported to surface water and/or sediments in Walnut or Woman Creek. Incidental ingestion of surface water and/or sediments is a potentially complete (significant) exposure pathway for the future off-site resident because it assumed that in the future scenario, storm water runoff from the site is not monitored, intercepted, or treated. Particulates in surface water resulting from disturbance to this medium may be ingested and will be accounted for in the surface water ingestion exposure pathway. Dermal contact with surface water and sediments in the future scenario is a relatively insignificant but potentially complete exposure pathway for this receptor. Soluble chemicals in sediments may be released to surface water and dermally absorbed, and will be accounted for in the dermal contact with surface water exposure pathway.

Groundwater in the UHSU either discharges to surface water in Walnut and Woman Creeks or is lost to evapotranspiration. The UHSU is hydraulically disconnected from the lower-confined aquifer by an impermeable claystone ranging from 15 to 30 meters (50 to 100 feet) in thickness (see Section 2.0). Thus, potential exposure pathways (including inhalation of indoor VOCs that may volatilize from groundwater) associated with domestic wells located west of Standley Lake and along the Woman Creek drainage are considered incomplete. There are no domestic wells located west of the Great Western Reservoir in the Walnut Creek drainage.

Semivolatile organic and inorganic chemicals bound to soil that are released via wind as particulate matter represent potential inhalation, oral and dermal exposure pathways. Future off-site residents may be directly exposed to airborne particulate matter via inhalation. Homegrown vegetables, contaminated by deposition of airborne particulates from the site, represent a potentially complete ingestion pathway. Contact with soil that is similarly contaminated represents potentially complete oral and dermal (both insignificant) exposure pathways for this receptor. Contact is assumed to occur in the direct vicinity of the residence.

As shown in the CSM, plant uptake of contaminants deposited as windblown particulates on soil may potentially occur. However, this uptake pathway is considered incomplete for the following reasons:

- As mentioned in Section 4.4, metals bind tightly to soil, thus greatly reducing their bioavailability to plants (EPA 1991a).

- Chemical concentrations from particulates deposited on residential soil will be significantly diluted by tilling.

For these reasons, chemical concentrations in garden vegetables, due to surface deposition of chemicals onto plants, are expected to be greater than chemicals taken up by vegetables from the soil contaminated by particulate deposition. It is expected that direct contact exposures to surface soil (dermal absorption and ingestion) will greatly exceed chemical intakes associated with plant uptake and subsequent ingestion and will, therefore, be negligible. Therefore, future residential intake of vegetables will only be evaluated based on surface deposition of particulates on plants.

External irradiation exposures to future off-site residents resulting from deposition of radionuclides via airborne particulate are expected to be an incomplete pathway since relatively low concentrations of radionuclides in off-site residential soils due to fugitive dust deposition are expected. In addition, the primary radionuclides of concern at the RFP, plutonium and americium, do not have highly penetrating radiation associated with them.

In summary, potentially complete human exposure pathways for chemicals released from contaminated site soils for the future off-site resident are:

- Soil ingestion (deposition of particulates on residential soil)
- Dermal contact with soil (surface deposition of particulates)
- Surface water/suspended sediment ingestion
- Dermal contact with surface water/suspended sediment
- Inhalation of particulates
- Ingestion of homegrown vegetables (surface deposition of particulates)

4.5.2.6 Future On-Site Resident

The CSM for the future on-site resident indicates that storm water runoff, volatilization, wind suspension, infiltration and percolation, direct contact, external irradiation, and uptake by vegetables and fruits/plants are the potential chemical release mechanisms from contaminated site soils to the environment. All these primary release mechanisms provide potential exposure routes to the future on-site resident.

Chemicals that are discharged from groundwater to surface water or that are released from site soils to surface water via storm water runoff may be transported to surface water and/or suspended sediments in Walnut or Woman Creek. Incidental ingestion of surface water and/or suspended sediments is a potentially complete (significant) exposure pathway for the future on-site resident because it assumed that in the future scenario, storm water runoff from the site is not monitored. Particulates in surface water resulting from disturbance to this medium may be ingested and will be accounted for in the surface water ingestion exposure pathway. Dermal contact with surface water and sediments in the future scenario is a relatively insignificant but potentially complete exposure pathway for this receptor. Soluble chemicals in sediments may be released to surface water and dermally absorbed, and will be accounted for in the dermal contact with surface water exposure pathway.

Although no domestic or commercial-use wells are located at the RFP, groundwater in the UHSU may be ingested by future on-site residents. Thus, this exposure pathway was considered potentially significant. Chemicals that volatilize from site groundwater and/or soils and are released to indoor air represent a potentially complete (significant) inhalation pathway to future on-site residents. Inhalation of outdoor VOCs is considered incomplete due to the expected dispersal and dilution.

Semivolatile organic and inorganic chemicals bound to soil that are released via wind as particulate matter represent potential inhalation, oral, dermal, and external irradiation exposure pathways. Future on-site residents may be directly exposed to airborne particulate matter via inhalation. Homegrown vegetables, contaminated by deposition of airborne particulates from the site, represent a potentially complete ingestion pathway. Contact with soil that is similarly contaminated represents potentially complete oral and dermal exposure pathways for the future on-site resident. These pathways will be accounted for as Direct Contact exposures in Figure 4-1.

As shown in the CSM, plant uptake of contaminants in soil may potentially occur. This uptake pathway is considered complete. As mentioned in Section 4.4, chemical concentrations in garden vegetables, due to surface deposition of chemicals onto plants, are expected to be greater than chemicals taken up by vegetables from the soil contaminated by particulate deposition. It is also expected that direct contact exposures to surface soil, dermal absorption (significant), and ingestion (insignificant) will greatly exceed chemical intakes associated with plant uptake. Nonetheless, plant uptake and subsequent ingestion of chemicals of concern will be evaluated for future on-site residents.

External irradiation exposures to future on-site residents are expected to be a complete (insignificant) pathway.

In summary, potentially complete human exposure pathways for chemicals released from contaminated site soils for the future off-site resident are:

- Surface water/suspended sediment ingestion
- Dermal contact with surface water/suspended sediment
- Inhalation of particulates
- Ingestion of homegrown vegetables (surface deposition of particulates and uptake)

- Inhalation of indoor VOCs
- Groundwater ingestion
- Soil ingestion
- Dermal contact with soil
- External irradiation

A summary of potentially complete exposure pathways that will be quantitatively evaluated in the baseline human health risk assessment is provided in Table 4-1.

TABLE 4-1
ROCKY FLATS PLANT
OU-2
POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED IN THE OU-2 HUMAN HEALTH RISK ASSESSMENT

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Off-site resident	Current	Soil ingestion Dermal contact with surface soil Ingestion of vegetables (surface deposition of particulates) Inhalation of airborne particulates
On-site worker	Current	Soil ingestion Dermal contact with surface soil Inhalation of airborne particulates External irradiation
On-site worker (Office and Construction)	Future	Soil ingestion Inhalation of indoor VOCs (office worker only) Inhalation of airborne particulates Dermal contact with soil External irradiation
On-site ecological researcher	Future	Soil ingestion Inhalation of airborne particulates Surface water/suspended sediment ingestion Dermal contact with surface soil Dermal contact with surface water/suspended sediment External irradiation

TABLE 4-1
(Concluded)

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Hypothetical off-site resident	Future	Soil ingestion Ingestion of vegetables (surface deposition of particulates) Inhalation of airborne particulates Surface water/suspended sediment ingestion Dermal contact with surface soil Dermal contact with surface water/suspended sediment
Hypothetical on-site resident	Future	Soil ingestion Ingestion of vegetables (uptake and surface deposition of particulates) Inhalation of airborne particulates Surface water/suspended sediment ingestion Dermal contact with surface soil Dermal contact with surface water/suspended sediment Inhalation of indoor VOCs Groundwater ingestion External irradiation

5.0 ESTIMATING CHEMICAL INTAKES

This section presents reasonable maximum intake parameters for each of the receptors and exposure pathways identified in the previous section. Chemical intakes are not present in this memorandum since they are dependent on pending site characterization chemical data and fate and transport modeling, as appropriate. The fate and transport models to be used in the OU-2 BRA will be presented as a separate Technical Memorandum.

Using the exposure point concentrations of chemicals in soils, surface water, and air, it is possible to estimate the potential human intake of those chemicals via each exposure pathway. Intakes are expressed in terms of milligram (mg) chemical ingested, inhaled or dermally absorbed per kilogram/body weight per day (mg/kg-day). Intakes are calculated following guidance in "Risk Assessment Guidance for Superfund" (EPA 1989a), the "Exposure Factors Handbook" (EPA 1989b), other EPA guidance documents as appropriate, and professional judgment regarding likely site-specific exposure conditions. Intakes are estimated using reasonable estimates of body weight, inhalation volume, ingestion rates, soil or food matrix effects, and frequency and duration of exposure.

Intakes are estimated for reasonable maximum exposure (RME) conditions. The RME is estimated by selecting values for exposure variables so that the combination of all variables results in the maximum exposure that can reasonably be expected to occur at the site.

The general equation for calculating intake in terms of mg/kg-day is:

$$\text{Intake} = \frac{\text{chemical conc.} * \text{contact rate} * \text{exposure frequency} * \text{exposure duration}}{\text{body weight} * \text{averaging time}}$$

with corresponding units of:

$$\text{mg/kg/day} = \frac{\text{mg/vol} * \text{vol/day} * \text{day/year} * \text{year}}{\text{kg} * \text{day}}$$

The variable "averaging time" is expressed in days to calculate daily intake. For noncarcinogenic chemicals, intakes are calculated by averaging over the period of exposure to yield an average daily intake. For carcinogens, intakes are calculated by averaging the total cumulative dose over a lifetime, yielding "lifetime average daily intake." Different averaging times are used for carcinogens and noncarcinogens because it is thought that their effects occur by different mechanisms. The approach for carcinogens is based on the current scientific opinion that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime. Therefore, for whatever duration, the intake of a carcinogen is averaged over a 70-year lifetime (EPA 1989a). Intake of noncarcinogens is averaged over the period of exposure since the average concentration of a noncarcinogen is compared with the threshold dose for an effect.

Omitting chemical concentrations from the intake equation yields an "intake factor" that is constant for each exposure pathway and receptor. The intake factor can then be multiplied by the concentration of each chemical to obtain the pathway-specific intake of that chemical. Intake factors are calculated separately for each potentially exposed receptor and exposure pathway that was identified in Section 4.5. Contact rates, such as dermal contact, caloric intake and inhalation (but not soil ingestion) are <u>approximately</u> proportional to body weight. It is acknowledged that body weight is not exactly proportional to surface area and that age-specific body weight/inhalation rates differ by factors of two or less. However, these differences are assumed to be negligible. Therefore, child residential intakes are not estimated for any exposure pathway except soil ingestion. The assumptions used in deriving intake factors are discussed below.

5.1 INTAKE FACTOR ASSUMPTIONS

Several exposure parameters, such as exposure duration, body weight, and averaging times, have general application in all intake estimations, regardless of pathway. These general assumptions, as well as pathway-specific assumptions, are detailed Section below 5.1.1. The term "occupational exposures" includes exposures to the current and future on-site worker and to the future ecological researcher.

5.1.1 General Exposure Assumptions

- For all exposure scenarios except dermal contact with surface water, the non-site-specific RME exposure frequency is 7 days/week for 50 weeks (350 days) for the current and future on- and off-site residents (EPA 1991b), 5 days/week for 50 weeks (250 days) for the current security and future ecological researcher and office workers on site (EPA 1991b). (Please note that EPA 1991b supersedes EPA 1989a and EPA 1989b.) These exposure frequencies assume that exposures occur routinely at the OU-2 site, when in fact, exposures are not routine and may not occur at all due to precipitation, snow cover, or frozen surface water. Information provided by the Assistant State Climatologist indicates that there are at least 60 days per year (in Lakewood, Colorado, approximately 5 miles southeast of the RFP) with at least 1 inch of snow cover on the ground, based on the 30-year average precipitation record (Doesken 1992). Therefore, 290 days per year is used instead of 350 days/year for oral and dermal exposure to soil and inhalation of particulates in residents, and 207 days per year is used for direct contact with soil and inhalation exposure to soil particulates in current on-site workers and future office workers. (This assumes that the 60 days of snow cover are continuous. Thus, 43 work days are subtracted from 250 work days per year).

- Residential RME exposure duration is assumed to be 30 years (EPA 1991b).

- Occupational RME exposure durations are assumed to be 25 years (EPA 1991b), except for the future on-site construction worker which is assumed to be exposed during building foundation work for 30 days.

- Averaging time for chemicals with noncarcinogenic effects is the product of the exposure duration and the number of days in a year (365).

- Averaging time for carcinogenic effects is 70 years (25,550 days) as discussed previously.

- The average adult body weight is assumed to be 70 kg (EPA 1989b). The average child body weight is assumed to be 15 kg (EPA 1991b).

5.1.2 Inhalation Assumptions

Uptake of chemicals through inhalation is a function of the volume of air inhaled per day, the exposure frequency and duration, and pulmonary deposition (for particulate inhalation). Intake parameters for exposure via indoor particulate inhalation were estimated for all receptors. An intake factor for exposure via VOC inhalation was estimated for the future on-site workers and the future on-site resident. The following assumptions will be used to estimate exposure to chemicals of concern through this route.

- The RME respiratory volume of air for all receptors is assumed to be 20 m^3/day (0.83 m^3/hr). This rate assumes that all of the exposure time is spent at activities equivalent to walking (EPA 1991b).

- On-site occupational receptors are assumed to breathe on-site air 8 hours/day in the RME case.

- Current and future residential receptors are assumed to inhale particulates 16 hours/day in the RME case. This exposure frequency assumes that residential receptors are at home for 16 hours/day and are at work, school, or otherwise away from their residence for 8 hours per day.

Indoor air particulate concentrations are assumed to be equal to outdoor air particulate concentrations.

- Twenty-five percent of inhaled particles are deposited in the lung; it is further assumed that all chemicals in that fraction are absorbed (MRI 1985).

5.1.3 Soil Ingestion Assumptions

Uptake of chemicals via incidental ingestion of soil and dust is a function of the ingestion rate, the fraction of ingested soil or dust that is contaminated, the frequency and duration of exposure, and the bioavailability of the chemical adhered to the soil particles ingested.

The calculation of an RME 30-year residential exposure to soil will be divided into two parts. First, a six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion. Second, a 24-year exposure duration is assessed for older children and adults using a lower soil ingestion rate. By time-averaging the child residential soil intake with the intake calculated for the adult, a child residential risk from soil ingestion is taken into account.

Intake factors for exposure via soil ingestion were calculated for an adult resident, a child resident, a future on-site ecological researcher, and a future on-site worker. The following assumptions will be used in estimating intake through this route.

- Occupational receptors are assumed to ingest 50 mg/day of soil in the RME case (EPA 1991b).

- The calculation of a 30-year residential exposure to soil is time-averaged by assessing a six-year exposure duration followed by a 24-year exposure duration. The six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg) (EPA 1991b). The 24-year exposure duration is assessed for older children and adults and accounts for the period of lower soil ingestion (100 mg/day) and an adult body weight (70 kg) (EPA 1991b).

- The fraction ingested (FI) from the contaminated source is assumed to be 0.06 for the current on-site worker, 0.125 for the future on-site office worker, 1.0 for the future on-site construction worker, 0.17 for the future on-site ecological researcher, and 0.5 for the current and future residential receptors. The FI for the current on-site worker is based on the approximate amount of time that a security guard spends in the OU-2 portion of the buffer zone each day (EG&G 1992d). The FI for the future on-site worker is based on 1 hour of exposure to contaminated soil per 8-hour workday. This assumes that the on-site worker spends his/her entire lunch hour outside. The future on-site ecological researcher is assumed to conduct research using the entire RFP as an ecological research area. The ratio of OU-2 (approximately 1,100 acres) relative to the entire RFP (approximately 6,550 acres) is 0.17. Residential receptors are assumed to be exposed to contaminated soils for the 16 hours per day that they are present at their homes, and are at work, school, or other locations for the other 8 hours. Thus 50 percent of their soil ingestion is from locations other than their residence.

- The matrix effect of soil on bioavailability of ingested contaminants is chemical-specific for all receptors. The matrix effect describes the reduced availability due to adsorption of chemicals to soil compared to the same chemical dose administered in solution. Therefore, the soil matrix has the effect of reducing chemical intake.

5.1.4 Homegrown Produce Ingestion Assumptions

Uptake of chemicals via ingestion of homegrown vegetables is a function of the ingestion rate, the fraction of contaminated homegrown produce ingested, the frequency and duration of exposure, and bioavailability of the chemical adhered to the produce ingested. It is assumed that contamination of homegrown produce may occur by surface deposition of particulates for current and future residents, and by direct uptake for future on-site residents only. An intake factor for exposure via vegetable ingestion was calculated for current and future residential receptors. The current and future on-site workers and the ecological researcher are not expected to ingest contaminated produce (see Section 4.5). The following assumptions will be used in estimating intake through this route.

- Current and future residential receptors are assumed to ingest 80,000 mg/day of vegetables in the RME case. This figure is based on the "typical" consumption value of vegetables (200,000 mg/day), assuming the "reasonable worst case" proportion that is homegrown as 40 percent (EPA 1991b).

- Homegrown vegetables are assumed to be potentially contaminated by surface deposition of airborne particulates from OU-2 soils, as described in Section 4.0. Modeled wet and dry deposition rates will be applied to reasonable maximum estimates of vegetable surface areas, weights, and human consumption rates to estimate chemical intake from this potential exposure pathway. Soil concentrations of chemicals will be multiplied by soil-to-plant partition coefficients to estimate uptake.

- The matrix effect of produce on bioavailability of ingested contaminants is assumed in the RME case unless chemical-specific information is available.

Reductions in chemical concentrations due to washing, cooking, or peeling of produce are not accounted for, which is likely to result in an overestimate of chemical concentrations in produce.

5.1.5 Surface Water/Suspended Sediment Ingestion Assumptions

Uptake of chemicals via surface water ingestion is a function of the daily intake rate, fraction ingested from the contaminated source, and exposure frequency and duration. Intake factors for surface water ingestion were calculated for the future ecological researcher and the future hypothetical residential receptor. The following assumptions will be used in estimating intake through this route.

- Both the future ecological researcher and hypothetical on- and off-site residents are assumed to ingest 0.05 liters of surface water per day (50 ml/day) (EPA 1989b).

- Because Walnut and Woman Creeks are separated by a relatively long distance, the risk associated with surface water and sediment in each stream will be assessed separately for future on-site residents. For the future ecological researcher, it is assumed that the entire RFP serves as the ecological study area. Thus, 50 percent of the surface water/sediment exposure will be from Walnut Creek and 50 percent will be from Woman Creek.

- The RME exposure frequency is assumed to be 7 events/year for the future ecological researcher and the future hypothetical on- and off-site residents (EPA 1989a).

5.1.6 Dermal Contact with Soil

Uptake of chemicals of concern through dermal contact with surface soil is a function of body surface area, absorbed fraction, an adherence factor that describes how much soil adheres to skin, the fraction of soil contacted that is from a contaminated source, and exposure frequency and duration. Dermal uptake of metals is negligible and is not addressed in human health risk assessments (EPA 1991a). Dermal contact with surface soil will only be evaluated if sampling demonstrates the presence of organic contaminants. The following assumptions will be used to estimate exposure to chemicals of concern through dermal contact with soil route for all receptors.

- The RME exposed body surface area for all receptors, but not all pathways, is assumed to be 2,910 cm^2/day. The reasonable maximum surface area is assumed to be 15 percent of total body surface (equivalent to face, forearms, and hands) (EPA 1989b).

- The absorbed fraction is the estimated fraction of organic compounds (if available) adhered to soil particles that partitions to and is absorbed through skin. This fraction is chemical-specific. Percent absorbed depends upon soil loading, organic carbon content of soil, contaminant concentration, duration of exposure, animal species used in the experiment, and whether the experiment is conducted in vitro or in vivo. The absorbed fraction will be determined on a chemical-specific basis using data available in the scientific literature.

- The soil adherence factor used is 0.5 mg/cm^2 in the RME case (Sedman 1989).

- The fraction contacted (FC) from the contaminated medium is assumed to be 0.06, 0.125, 0.17, and 0.5 in the RME case for the current on-site worker, future on-site office worker, the future on-site ecological researcher, and the current and future residential receptors, respectively. These values are based on the amount of direct contact with soils at OU-2 versus other areas outside OU-2 as previously discussed for soil ingestion.

5.1.7 Dermal Contact with Surface Water

Uptake of chemicals through dermal contact with surface water is a function of body surface area, a chemical-specific permeability constant, and exposure time, frequency, and duration. Dermal uptake of metals (including radionuclides) will only be addressed for this medium for the soluble fraction of metals. Therefore, dermal contact with surface water will only be evaluated if sampling demonstrates the presence of organic chemicals or soluble metals. Dermal absorption of chemicals in sediment that is disturbed during surface water contact events will be accounted for as part of this exposure pathway by incorporating a suspended sediment factor into the surface water model used to calculate exposure point concentrations in water. The following assumptions were used to estimate exposure to chemicals of concern through dermal contact with the surface water route from a wading scenario for the future on- and off-site residential receptors and the ecological researcher.

- The RME exposed body surface area for future residential receptors and the ecological researcher is assumed to be 4,850 cm^2/day because they may remove their shoes and roll up their pant legs while wading. The reasonable maximum surface area is assumed to be 25 percent of total body surface (equivalent to hands, feet, and lower legs) (EPA 1989b).

- The water permeability constant of 8.0E-04 cm/hour is used. However, the chemical-specific permeability constants for aqueous solutions will be used, if available, when the contaminants of concern are identified.

- The RME exposure time is assumed to be 2.6 hours per day for both the future residential receptors and the ecological researcher (EPA 1989a).

- The exposure frequency is assumed to be 7 events per year for both the future ecological researcher and the future residential receptors (EPA 1989a).

5.1.8 Internal Exposure to Radionuclides

Internal exposure to radionuclides identified as chemicals of concern will be evaluated in two ways. First, the dose equivalent based on intake of radionuclides via ingestion or inhalation will be calculated and compared to radiation protection standards. The second method for evaluation of internal radionuclide exposure will be conducted by calculating the intake of radionuclides and multiplying that intake by EPA-derived carcinogenic slope factors for each radionuclide of concern (EPA 1989a). The result of this calculation will be the unitless carcinogenic risk associated with ingestion or inhalation of a given radionuclide of concern.

Calculation of intake for radionuclides is conducted in a similar manner as for nonradioactive chemicals of concern. Intake of radionuclides by either ingestion or inhalation is a function of radionuclide concentration, contact rate (or the amount of contaminated medium contacted per unit time or event), and exposure frequency and duration. The only difference between calculating intake for radionuclides and nonradioactive substances is that the averaging time and body weight are excluded as divisors from the intake equation. The intake of radionuclides through inhalation or ingestion can be estimated using the following equation:

$$Intake_{,int} = C * IR * EF * ED$$

Where:

$Intake_{,int}$	=	Internal radionuclide intake via inhalation or ingestion (Bq).
C	=	Concentration of a radionuclide at the exposure point (Bq/m^3, Bq/l or Bq/kg).
IR	=	Intake rate (breathing rate (m^3/day), ingestion rate (kg/day), or drinking rate (l/day)).
EF, ED	=	Exposure frequency and duration (e.g., how long and how often exposure occurs [days/year * years]).

The resulting calculation is an estimate of the radionuclide intake, expressed in units of activity (e.g., Bq) (EPA 1989a). This value is then multiplied by either a dose coefficient or a carcinogenic slope factor to estimate equivalent dose or carcinogenic risk, respectively. The dose coefficient (DC - expressed in units of Sv per Bq) is used to estimate the equivalent dose (Sv), which can then be compared to a radiation protection standard. The cancer slope factor for radionuclides of concern are multiplied by the estimated radionuclide intake (either inhaled or ingested) to estimate risk (EPA 1989a).

5.1.9 External Irradiation

External exposure to radionuclides will be evaluated in a similar manner as internal radionuclide exposure. The equivalent dose will first be calculated for comparison with radiation protection standards. The cancer risks for ground surface irradiation will be computed using the EPA-derived external slope factor, the soil concentration, and the frequency and duration of the exposure for each radionuclide per EPA guidance (EPA 1989a).

To estimate the equivalent dose, radionuclide concentrations on the ground surface (Bq/m^2) whether directly measured or predicted by modeling, will be multiplied by the external dose coefficient for specific radionuclides (Sv/hr per Bq/m^2) and the duration of exposure (hours) (EPA 1989a). This will result in an estimate of the equivalent dose, which can then be compared to radiation protection standards. Equivalent doses from external exposure to radioactively contaminated ground surfaces do not require internal adjustment factors, such as uptake rate, bioavailability, or body weight. The equation for estimating equivalent dose from external radiation exposure is as follows:

$$H_{T,ext} = C * EF * ED * DC$$

Where:

$H_{T,ext}$	=	External equivalent dose of radiation received through ground surface exposure (Sv).
C	=	Concentration of a contaminant at the exposure point (Bq/m^2).
EF, ED	=	Exposure frequency and duration (i.e., time period exposed to contaminated air or soil (hours)).
DC	=	Dose coefficient (Sv/hr per Bq/m^2).

The carcinogenic risks for the ground surface pathway will be computed as the product of the external slope factor (Risk/yr per Bq/g soil), the soil concentration (Bq/g soil), and the frequency and duration of the exposure (years) for each radionuclide as indicated below:

$$Risk = C * EF * ED * CSF$$

Where:

Risk	=	External equivalent dose of radiation received through ground surface exposure (unitless).
C	=	Concentration of a contaminant at the exposure point (Bq/g soil).
EF, ED	=	Exposure frequency and duration (i.e., time period exposed to contaminated air or soil [years]).
CSF	=	External Cancer Slope Factor (Risk/yr per Bq/g soil).

5.2 INTAKE FACTOR CALCULATIONS

The above assumptions and values will be used to calculate intake factors for each exposure pathway and receptor. Parameters to be used for calculations of intake factors are shown in Tables 5-1 through 5-30. Exposure point concentrations will be used with these parameters to obtain pathway-specific intakes.

TABLE 5-1

INHALATION OF PARTICULATES
CURRENT OFF-SITE RESIDENT

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$$

	Parameter	RME
IR =	Inhalation rate (m^3/hr)[1]	0.83
ET =	Exposure time (hours/day)[2]	16
EF =	Exposure frequency (days/year)[3]	290
ED =	Exposure duration (years)[4]	30
DF =	Deposition factor	0.25
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).

(2) This RME exposure time assumes that 16 hours per day are spent at home and that 8 hours per day are spent at school, work or other locations.

(3) Assumes that residents take 15 days per year vacation (EPA 1991b) and includes 60 days per year snow cover (Doesken 1992).

(4) Source: EPA 1991b.

(5) Twenty-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed (MRI 1985).

TABLE 5-2

SOIL INGESTION
CURRENT OFF-SITE RESIDENT (ADULT AND CHILD)[1]

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME Adult	RME Child
IR =	Ingestion rate (mg/day)[1]	100	200
FI =	Fraction ingested from contaminated source[2]	0.5	0.5
ME =	Matrix effect[3]	chemical specific	
EF =	Exposure frequency (days/year)[4]	290	290
ED =	Exposure duration (years)[5]	24	6
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	15
AT =	Averaging time (days)		
	Noncarcinogenic	8,760	2,190
	Carcinogenic	25,550	25,550

(1) The calculation of a 30-year residential exposure to soil is divided into two parts. First, a six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second, a 24-year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg). These two periods are then time-averaged (EPA 1991b).

(2) The FI assumes that residents are at home for 16 hours per day and at work, school, or other locations for 8 hours per day.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes that residents take 15 days per year vacation (EPA 1991b) and includes 60 days per year snow cover (Doesken 1992).

(5) Source: EPA 1991b.

TABLE 5-3

DERMAL CONTACT WITH SURFACE SOIL
CURRENT OFF-SITE RESIDENT

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
SA =	Surface area (cm^2)[1]	2,910
AB =	Absorption factor[2]	chemical-specific
AF =	Adherence factor (mg/cm^2)[3]	0.5
FC =	Fraction contacted from contaminated source[4]	0.5
EF =	Exposure frequency (days/year)[5]	290
ED =	Exposure duration (years)[6]	30
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) The RME surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989b).

(2) Dermal absorption of metals from a soil matrix is negligible (EPA 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be less than one and will be determined on a chemical-specific basis.

(3) Source: Sedman 1989.

(4) The FC assumes that residents are at home for 16 hours per day and are at work, school, or other locations for 8 hours per day.

(5) Assumes that residents take 15 days per year vacation (EPA 1991b) and includes 60 days per year snow cover (Doesken 1992).

(6) Source: EPA 1991b.

TABLE 5-4

INGESTION OF HOMEGROWN VEGETABLES (SURFACE DEPOSITION OF PARTICULATES) CURRENT OFF-SITE RESIDENT

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
IR:	Ingestion rate, vegetables (mg/day)[1]	80,000
FI:	Fraction ingested from contaminated source	1.0
ME:	Matrix effect[2]	chemical-specific
EF:	Exposure frequency (days/year)[3]	350
ED:	Exposure duration (years)[3]	30
CF:	Conversion factor (kg/mg)	10^{-6}
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This ingestion rate is based on the typical consumption value of vegetables (200,000 mg/day), with the "reasonable worst case" proportion that is homegrown assumed to be 40 percent (EPA 1991b).

(2) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(3) Source: EPA 1991b.

TABLE 5-5

INHALATION OF PARTICULATES
CURRENT ON-SITE WORKER

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$$

	Parameter	RME
IR =	Inhalation rate (m^3/hr)[1]	0.83
ET =	Exposure time (hours/day)[2]	0.5
EF =	Exposure frequency (days/year)[3]	207
ED =	Exposure duration (years)[4]	25
DF =	Deposition factor[5]	0.25
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).

(2) Based on the amount of time security personnel spend patrolling the OU-2 portion of the buffer zone. EG&G 1992d.

(3) Assumes that occupational receptor works 5 days per week for 50 weeks per year and takes 2 weeks of vacation per year (EPA 1991b). In addition, 60 days of continuous snow cover (i.e., 43 work days) per year is assumed (Doesken 1992).

(4) Source: EPA 1991b.

(5) Twenty-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all of the chemicals in that fraction are absorbed (MRI 1985).

TABLE 5-6

SOIL INGESTION
CURRENT ON-SITE WORKER

$$\text{Intake Factor} = \frac{\text{IR x FI x ME x EF x ED x CF}}{\text{BW x AT}}$$

	Parameter	RME
IR =	Ingestion rate (mg/day)[1]	50
FI =	Fraction ingested from contaminated source[2]	0.06
ME =	Matrix effect[3]	chemical-specific
EF =	Exposure frequency (days/year)[4]	207
ED =	Exposure duration (years)[5]	25
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) Source: EPA (1991b) (supersedes EPA 1989a).

(2) Based on the amount of time security personnel spend patrolling the OU-2 portion of the buffer zone. EG&G 1992d.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes that occupational receptor works 5 days per week for 50 weeks per year and takes 2 weeks of vacation per year (EPA 1991b). In addition, 60 days of continuous snow cover (i.e., 43 work days) per year is assumed (Doesken 1992).

(5) Source: EPA 1991b.

TABLE 5-7

DERMAL CONTACT WITH SURFACE SOIL
CURRENT ON-SITE WORKER

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
SA =	Surface area (cm^2)[(1)]	2,910
AB =	Absorption factor[(2)]	chemical-specific
AF =	Adherence factor (mg/cm^2)[(3)]	0.5
FC =	Fraction contacted from contaminated source[(4)]	0.06
EF =	Exposure frequency (days/year)[(5)]	207
ED =	Exposure duration (years)[(6)]	25
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) The surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989b).

(2) Dermal absorption of metals from a soil matrix is negligible (EPA 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be less than one and will be determined on a chemical-specific basis.

(3) Source: Sedman 1989.

(4) Based on the amount of time security personnel spend patrolling the OU-2 portion of the buffer zone. EG&G 1992d.

(5) Assumes that occupational receptor works 5 days per week for 50 weeks per year and takes 2 of weeks of vacation per year (EPA 1991b). In addition, 60 days of continuous snow cover (i.e., 43 work days) per year is assumed (Doesken 1992).

(6) Source: EPA 1991b.

TABLE 5-8

INHALATION OF INDOOR AIR VOCs
FUTURE ON-SITE WORKER (OFFICE ONLY)

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED}{BW \times AT}$$

Parameter		RME
IR =	Inhalation rate (m^3/hr)[1]	0.83
ET =	Exposure time (hours/day)[2]	8
EF =	Exposure frequency (days/year)[3]	250
ED =	Exposure duration (years)[3]	25
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).
(2) The ET is based on an 8-hour workday.
(3) Source: EPA 1991b.

TABLE 5-9

INHALATION OF PARTICULATES
FUTURE ON-SITE WORKERS (OFFICE AND CONSTRUCTION)

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$$

	Parameter	RME Office	RME Construction
IR =	Inhalation rate (m^3/hr)[1]	0.83	0.83
ET =	Exposure time (hours/day)	0.5[2]	8
EF =	Exposure frequency (days/year)	207[3]	30[4]
ED =	Exposure duration (years)	25	1.0
DF =	Deposition factor[5]	0.25	0.25
BW =	Body weight (kg)	70	70
AT =	Averaging time (days)		
	Noncarcinogenic	9,125	365
	Carcinogenic	25,550	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).
(2) Based on the amount of time security personnel spend patrolling the OU-2 portion of the buffer zone. EG&G 1992d.
(3) Assumes that occupational receptor works 5 days per week for 50 weeks per year and takes 2 weeks of vacation per year (EPA 1991b). In addition, 60 days of continuous snow cover (i.e., 43 work days) per year is assumed (Doesken 1992).
(4) Based on the expected number of days required to construct a building foundation.
(5) Twenty-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all of the chemicals in that fraction are absorbed (MRI 1985).

TABLE 5-10

SOIL INGESTION
FUTURE ON-SITE WORKERS (OFFICE AND CONSTRUCTION)

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME Office	RME Construction
IR =	Ingestion rate (mg/day)[(1)]	50	50
FI =	Fraction ingested from contaminated source	0.125[(2)]	1.0
ME =	Matrix effect[(3)]	chemical-specific	
EF =	Exposure frequency (days/year)	207[(4)]	30[(5)]
ED =	Exposure duration (years)	25	1.0
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	70
AT =	Averaging time (days)		
	Noncarcinogenic	9,125	365
	Carcinogenic	25,550	25,550

(1) Source: EPA 1991b (supersedes EPA 1989a).

(2) Based on 1-hour of exposure to soil per 8-hour workday.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes that occupational receptor works 5 days per week for 50 weeks per year and takes 2 weeks of vacation per year (EPA 1991b). In addition, 60 days of continuous snow cover (i.e., 43 work days) per year is assumed (Doesken 1992).

(5) Based on the expected number of days required to construct a building foundation.

TABLE 5-11

DERMAL CONTACT WITH SURFACE SOIL
FUTURE ON-SITE WORKERS (OFFICE AND CONSTRUCTION)

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME Office	RME Construction
SA =	Surface area (cm^2)[1]	2,910	2,910
AB =	Absorption factor[2]	chemical-specific	chemical-specific
AF =	Adherence factor (mg/cm^2)[3]	0.5	0.5
FC =	Fraction contacted from contaminated source	0.125[4]	1.0
EF =	Exposure frequency (days/year)	207[5]	30[6]
ED =	Exposure duration (years)	25	1.0
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	70
AT =	Averaging time (days)		
	Noncarcinogenic	9,125	30
	Carcinogenic	25,550	25,550

(1) The RME surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989b).

(2) Absorption of metals from a soil matrix is negligible (EPA 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be lower and will be determined on a chemical-specific basis.

(3) Source: Sedman 1989.

(4) Based on 1 hour of exposure to soil per 8-hour workday.

(5) Assumes that occupational receptor works 5 days per week for 50 weeks per year and takes 2 weeks of vacation per year (EPA 1991b). In addition, 60 days of continuous snow cover (i.e., 43 work days) per year is assumed (Doesken 1992).

(6) Based on the expected number of days required to construct a building foundation.

TABLE 5-12

SURFACE WATER/SUSPENDED SEDIMENT INGESTION
FUTURE ON-SITE ECOLOGICAL RESEARCHER

$$\text{Intake Factor} = \frac{IR \times EF \times ED \times FI}{BW \times AT}$$

	Parameter	RME
IR :	Intake rate (l/event)[1]	0.05
EF :	Exposure frequency (events/year)[2]	7
ED:	Exposure duration (years)[3]	25
FI:	Fraction ingested from contaminated source	1.0
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) Equivalent to 50 ml of incidental surface water ingestion per day for on-site surface water research (EPA 1989b).

(2) Source: EPA 1989a.

(3) Source: EPA 1991b.

TABLE 5-13

DERMAL CONTACT WITH SURFACE WATER/SUSPENDED SEDIMENT FUTURE ON-SITE ECOLOGICAL RESEARCHER

$$\text{Intake Factor} = \frac{SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
SA =	Surface area (cm^2)[1]	4,850
PC =	Permeability constant (cm/hr)[2]	8.0E-04
ET =	Exposure time (hours/event)[3]	2.6
EF =	Exposure frequency (events/year)[3]	7
ED =	Exposure duration (year)[4]	25
CF =	Conversion factor (l/cm^3)	10^{-3}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) The RME surface area is equivalent to hands, feet, and lower legs, or 25 percent of total body surface (EPA 1989b).

(2) The permeability constant of water is used, but chemical-specific permeability constants will be used, if available, for aqueous solutions.

(3) Source: EPA 1989a.

(4) Source: EPA 1991b.

TABLE 5-14

INHALATION OF PARTICULATES
FUTURE ON-SITE ECOLOGICAL RESEARCHER

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF \times FI}{BW \times AT}$$

	Parameter	RME
IR =	Inhalation rate (m^3/hr)(1)	0.83
ET =	Exposure time (hours/day)(2)	8
EF =	Exposure frequency (days/year)(3)	207
ED =	Exposure duration (years)(4)	25
DF =	Deposition factor (5)	0.25
FI =	Fraction Inhaled(6)	0.17
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).
(2) The ET assumes an 8-hour workday.
(3) Assumes that occupational receptor works 5 days per week for 50 weeks per year and takes 2 weeks of vacation per year (EPA 1991b). In addition, 60 days of continuous snow cover (i.e., 43 work days) per year is assumed (Doesken 1992).
(4) Source: EPA 1991b.
(5) Twenty-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed (MRI 1985).
(6) Assumes that the OU-2 area (approximately 1,100 acres) is one portion of the entire RFP ecological study area (RFP acreage is approximately 6,550 acres).

TABLE 5-15

SOIL INGESTION
FUTURE ON-SITE ECOLOGICAL RESEARCHER

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
IR =	Ingestion rate (mg/day)[(1)]	50
FI =	Fraction ingested from contaminated source[(2)]	0.17
ME =	Matrix effect[(3)]	chemical-specific
EF =	Exposure frequency (days/year)[(4)]	207
ED =	Exposure duration (years)[(5)]	25
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) Source: EPA 1991b.

(2) Assumes that the OU-2 area (approximately 1,100 acres) is one portion of the entire RFP ecological study area (RFP acreage is approximately 6,550 acres).

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes that occupational receptor works 5 days per week for 50 weeks per year and takes 2 weeks of vacation per year (EPA 1991b). In addition, 60 days of continuous snow cover (i.e., 43 work days) per year is assumed (Doesken 1992).

(5) Source: EPA 1991b (supersedes EPA 1989a).

TABLE 5-16

DERMAL CONTACT WITH SURFACE SOIL
FUTURE ON-SITE ECOLOGICAL RESEARCHER

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
SA =	Surface area (cm^2)[(1)]	2,910
AB =	Absorption factor[(2)]	chemical-specific
AF =	Adherence factor (mg/cm^2)[(3)]	0.5
FC =	Fraction contacted from contaminated source[(4)]	0.17
EF =	Exposure frequency (days/year)[(5)]	207
ED =	Exposure duration (years)[(6)]	25
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	9,125
	Carcinogenic	25,550

(1) The surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989b).

(2) Dermal absorption of metals from a soil matrix is negligible (EPA 1991a). The absorption factor for semivolatiles, volatiles, and other organics is likely to be less than one and will be determined on a chemical-specific basis when data become available.

(3) Source: Sedman 1989.

(4) Assumes that the OU-2 area (approximately 1,100 acres) is one portion of the entire RFP ecological study area (RFP acreage is approximately 6,550 acres).

(5) Assumes that occupational receptor works 5 days per week for 50 weeks per year and takes 2 weeks of vacation per year (EPA 1991b). In addition, 60 days of continuous snow cover (i.e., 43 work days) per year is assumed (Doesken 1992).

(6) Source: EPA 1991b.

TABLE 5-17

SURFACE WATER/SUSPENDED SEDIMENT INGESTION HYPOTHETICAL FUTURE ON-SITE RESIDENT

$$\text{Intake Factor} = \frac{IR \times EF \times ED}{BW \times AT}$$

	Parameter	RME
IR :	Intake rate (l/event)[(1)]	0.05
EF :	Exposure frequency (events/year)[(2)]	7
ED:	Exposure duration (years)[(3)]	30
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) Equivalent to 50 ml of incidental surface water ingestion per day (EPA 1989b).
(2) Source: EPA 1989a.
(3) Source: EPA 1991b.

TABLE 5-18

DERMAL CONTACT WITH SURFACE WATER/SUSPENDED SEDIMENT HYPOTHETICAL FUTURE ON-SITE RESIDENT

$$\text{Intake Factor} = \frac{SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
SA =	Surface area (cm^2)[1]	4,850
PC =	Permeability constant (cm/hr)[2]	8.0E-04
ET =	Exposure time (hours/event)[3]	2.6
EF =	Exposure frequency (events/year)[3]	7
ED =	Exposure duration (year)[4]	30
CF =	Conversion factor (l/cm^3)	10^{-3}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) The RME surface area is equivalent to hands, feet, and lower legs, or 25 percent of total body surface (EPA 1989b).
(2) The permeability constant of water is used, but chemical-specific permeability constants will be used when available for aqueous solutions.
(3) Source: EPA 1989a.
(4) Source: EPA 1991b.

TABLE 5-19

INHALATION OF PARTICULATES
HYPOTHETICAL FUTURE ON-SITE RESIDENT

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$$

	Parameter	RME
IR =	Inhalation rate (m^3/hr)[1]	0.83
ET =	Exposure time (hours/day)[2]	16
EF =	Exposure frequency (days/year)[3]	290
ED =	Exposure duration (years)[4]	30
DF =	Deposition factor [5]	0.25
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).

(2) This RME exposure time assumes that 16 hours per day is spent at home, and that 8 hours are spent at work, school or other location.

(3) Assumes that residents take 15 days per year vacation (EPA 1991b) and includes 60 days per year snow cover (Doesken 1992).

(4) Source: EPA 1991b.

(5) Twenty-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed (MRI 1985).

TABLE 5-20

INGESTION OF HOMEGROWN VEGETABLES (SOIL UPTAKE AND SURFACE DEPOSITION OF PARTICULATES) HYPOTHETICAL FUTURE ON-SITE RESIDENT

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
IR:	Ingestion rate, vegetables (mg/day)[1]	80,000
FI:	Fraction ingested from contaminated source	1.0
ME:	Matrix effect[2]	chemical-specific
EF:	Exposure frequency (meals/year)[3]	350
ED:	Exposure duration (years)[3]	30
CF:	Conversion factor (kg/mg)	10^{-6}
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This ingestion rate is based on the typical consumption value of vegetables (200,000 mg/day) with the "reasonable worst case" proportion that is homegrown assumed to be 40 percent (EPA 1991b).

(2) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(3) Source: EPA 1991b.

TABLE 5-21

INHALATION OF VOCs
FUTURE ON-SITE RESIDENTS

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED}{BW \times AT}$$

Parameter		RME
IR =	Inhalation rate (m^3/hr)[(1)]	0.83
ET =	Exposure time (hours/day)[(2)]	16
EF =	Exposure frequency (days/year)[(3)]	350
ED =	Exposure duration (years)[(3)]	30
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).

(2) RME exposure time assumes that 16 hours per day are spent at home, and 8 hours per day are spent at work, school or other locations.

(3) Source: EPA 1991b (supersedes EPA 1989a).

TABLE 5-22

UHSU GROUNDWATER INGESTION
HYPOTHETICAL FUTURE ON-SITE RESIDENT

$$\text{Intake Factor} = \frac{IR \times EF \times ED \times FI}{BW \times AT}$$

	Parameter	RME
IR :	Intake rate (l/day)[1]	2.0
EF :	Exposure frequency (days/year)[1]	350
ED:	Exposure duration (years)[1]	30
FI:	Fraction ingested from contaminated source	1.0
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) Source: EPA 1991b.

TABLE 5-23

SOIL INGESTION
HYPOTHETICAL FUTURE ON-SITE RESIDENT (ADULT AND CHILD)[1]

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME	
		Adult	Child
IR =	Ingestion rate (mg/day)[1]	100	200
FI =	Fraction ingested from contaminated source[2]	0.5	0.5
ME =	Matrix effect[3]	chemical-specific	
EF =	Exposure frequency (days/year)[4]	290	290
ED =	Exposure duration (years)[5]	24	6
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	15
AT =	Averaging time (days)		
	Noncarcinogenic	8,760	2,190
	Carcinogenic	25,550	25,550

(1) The calculation of a 30-year residential exposure to soil is divided into two parts. First, a six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second, a 24-year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg). These two periods are then time-averaged (EPA 1991b).

(2) The FI assumes that residents are at home for 16 hours per day and at work, school, or other locations for 8 hours per day.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes that residents take 15 days per year vacation (EPA 1991b) and includes 60 days per year snow cover (Doesken 1992).

(5) Source: EPA 1991b.

TABLE 5-24

**DERMAL CONTACT WITH SURFACE SOIL
HYPOTHETICAL FUTURE ON-SITE RESIDENT**

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
SA =	Surface area (cm²)(1)	2,910
AB =	Absorption factor(2)	chemical-specific
AF =	Adherence factor (mg/cm²)(3)	0.5
FC =	Fraction contacted from contaminated source(4)	0.5
EF =	Exposure frequency (days/year)(5)	290
ED =	Exposure duration (years)(6)	30
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) The RME surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989b).

(2) Dermal absorption of metals from a soil matrix is assumed to be zero (EPA 1991a). The absorption factor for semivolatile, volatile, and other organics is likely to be less than one and will be determined on a chemical-specific basis.

(3) Source: Sedman 1989.

(4) The FC assumes that residents are at home for 16 hours per day and are at work, school, or other locations for 8 hours per day.

(5) Assumes that residents take 15 days per year vacation (EPA 1991b) and includes 60 days per year snow cover (Doesken 1992).

(6) Source: EPA 1991b.

TABLE 5-25

SURFACE WATER/SUSPENDED SEDIMENT INGESTION
HYPOTHETICAL FUTURE OFF-SITE RESIDENT

$$\text{Intake Factor} = \frac{IR \times EF \times ED \times FI}{BW \times AT}$$

	Parameter	RME
IR :	Intake rate (l/event)[1]	0.05
EF :	Exposure frequency (events/year)[2]	7
ED:	Exposure duration (years)[3]	30
FI:	Fraction ingested from contaminated source	1.0
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) Equivalent to 50 ml of incidental surface water ingestion per day (EPA 1989b).
(2) Source: EPA 1989a.
(3) Source: EPA 1991b.

TABLE 5-26

DERMAL CONTACT WITH SURFACE WATER/SUSPENDED SEDIMENT HYPOTHETICAL FUTURE OFF-SITE RESIDENT

$$\text{Intake Factor} = \frac{SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
SA =	Surface area (cm^2)[1]	4,850
PC =	Permeability constant (cm/hr)[2]	8.0E-04
ET =	Exposure time (hours/event)[3]	2.6
EF =	Exposure frequency (events/year)[3]	7
ED =	Exposure duration (year)[4]	30
CF =	Conversion factor (l/cm^3)	10^{-3}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) The RME surface area is equivalent to hands, feet, and lower legs, or 25 percent of total body surface (EPA 1989b).
(2) The permeability constant of water is used, but chemical-specific permeability constants will be used when available for aqueous solutions.
(3) Source: EPA 1989a.
(4) Source: EPA 1991b.

TABLE 5-27

INHALATION OF PARTICULATES
HYPOTHETICAL FUTURE OFF-SITE RESIDENT

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$$

	Parameter	RME
IR =	Inhalation rate (m^3/hr)[(1)]	0.83
ET =	Exposure time (hours/day)[(2)]	16
EF =	Exposure frequency (days/year)[(3)]	290
ED =	Exposure duration (years)[(4)]	30
DF =	Deposition factor [(5)]	0.25
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This is equivalent to 20 m^3/day (EPA 1991b).

(2) This RME exposure time assumes that 16 hours per day is spent at home, and that 8 hours are spent at work, school or other location.

(3) Assumes that residents take 15 days per year vacation (EPA 1991b) and includes 60 days per year snow cover (Doesken 1992).

(4) Source: EPA 1991b.

(5) Twenty-five percent of inhaled particles are deposited and remain in the lung; it is assumed that all chemicals in that fraction are absorbed (MRI 1985).

TABLE 5-28

INGESTION OF HOMEGROWN VEGETABLES (SURFACE DEPOSITION OF PARTICULATES) HYPOTHETICAL FUTURE OFF-SITE RESIDENT

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
IR:	Ingestion rate, vegetables (mg/day)(1)	80,000
FI:	Fraction ingested from contaminated source	1.0
ME:	Matrix effect(2)	chemical-specific
EF:	Exposure frequency (meals/year)(3)	350
ED:	Exposure duration (years)(3)	30
CF:	Conversion factor (kg/mg)	10^{-6}
BW:	Body weight (kg)	70
AT:	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) This ingestion rate is based on the typical consumption value of vegetables (200,000 mg/day) with the "reasonable worst case" proportion that is homegrown assumed to be 40 percent (EPA 1991b).

(2) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(3) Source: EPA 1991b.

TABLE 5-29

SOIL INGESTION
HYPOTHETICAL FUTURE OFF-SITE RESIDENT (ADULT AND CHILD)[1]

$$\text{Intake Factor} = \frac{IR \times FI \times ME \times EF \times ED \times CF}{BW \times AT}$$

Parameter		RME	
		Adult	Child
IR =	Ingestion rate (mg/day)[1]	100	200
FI =	Fraction ingested from contaminated source[2]	0.5	0.5
ME =	Matrix effect[3]	chemical-specific	
EF =	Exposure frequency (days/year)[4]	290	290
ED =	Exposure duration (years)[5]	24	6
CF =	Conversion factor (kg/mg)	10^{-6}	10^{-6}
BW =	Body weight (kg)	70	15
AT =	Averaging time (days)		
	Noncarcinogenic	8,760	2,190
	Carcinogenic	25,550	25,550

(1) The calculation of a 30-year residential exposure to soil is divided into two parts. First, a six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg). Second, a 24-year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg). These two periods are then time-averaged (EPA 1991b).

(2) The FI assumes that residents are at home for 16 hours per day and at work, school, or other locations for 8 hours per day.

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution. Therefore, the soil matrix has the effect of reducing the intake of the compound. A matrix effect value of 1.0 is used unless chemical-specific data are available.

(4) Assumes that residents take 15 days per year vacation (EPA 1991b) and includes 60 days per year snow cover (Doesken 1992).

(5) Source: EPA 1991b.

TABLE 5-30

DERMAL CONTACT WITH SURFACE SOIL
HYPOTHETICAL FUTURE OFF-SITE RESIDENT

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

	Parameter	RME
SA =	Surface area (cm^2)[1]	2,910
AB =	Absorption factor[2]	chemical-specific
AF =	Adherence factor (mg/cm^2)[3]	0.5
FC =	Fraction contacted from contaminated source[4]	0.5
EF =	Exposure frequency (days/year)[5]	290
ED =	Exposure duration (years)[6]	30
CF =	Conversion factor (kg/mg)	10^{-6}
BW =	Body weight (kg)	70
AT =	Averaging time (days)	
	Noncarcinogenic	10,950
	Carcinogenic	25,550

(1) The RME surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989b).

(2) Dermal absorption of metals from a soil matrix is assumed to be zero (EPA 1991a). The absorption factor for semivolatile, volatile, and other organics is likely to be less than one and will be determined on a chemical-specific basis.

(3) Source: Sedman 1989.

(4) The FC assumes that residents are at home for 16 hours per day and are at work, school, or other locations for 8 hours per day.

(5) Assumes that residents take 15 days per year vacation (EPA 1991b) and includes 60 days per year snow cover (Doesken 1992).

(6) Source: EPA 1991b.

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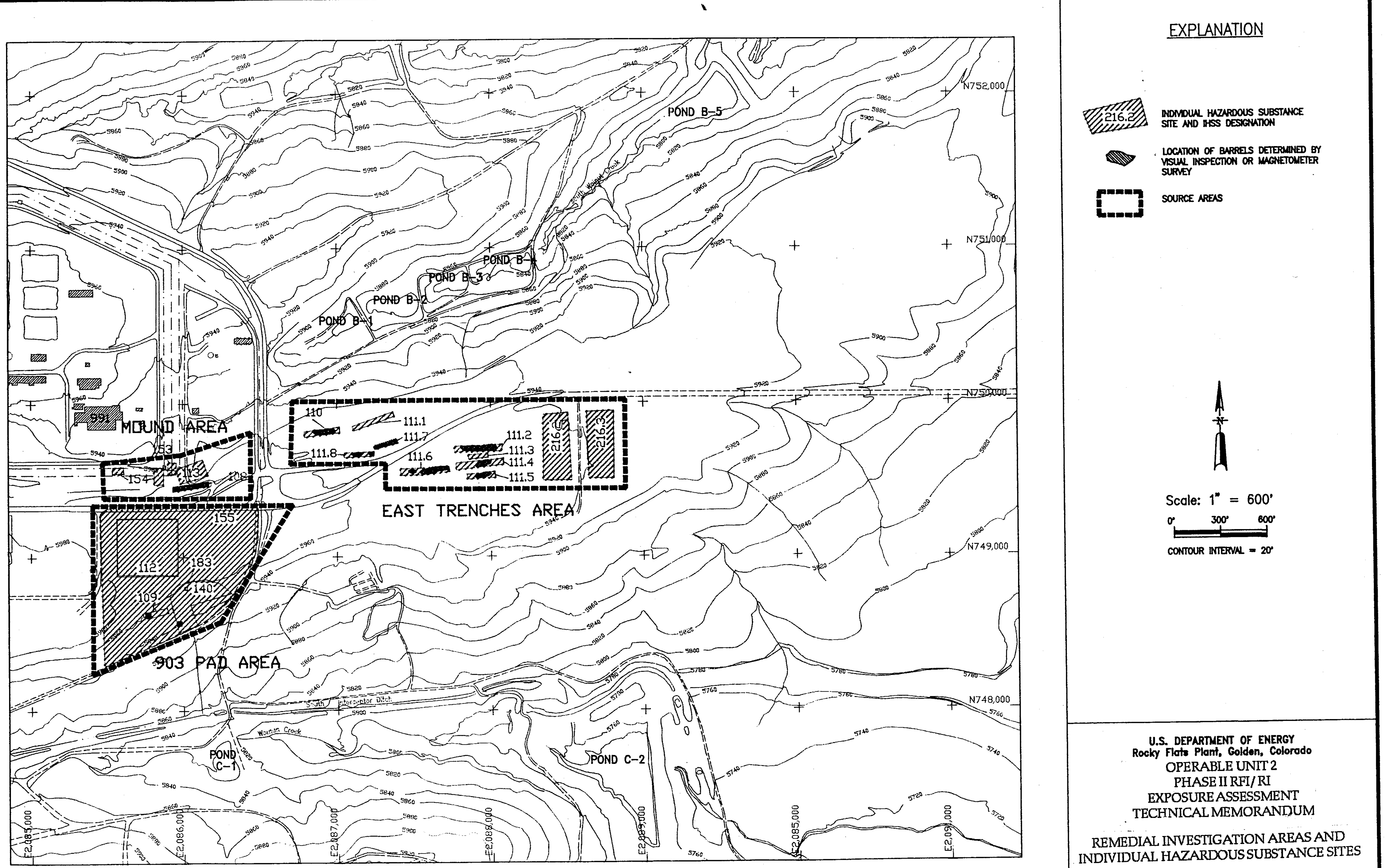


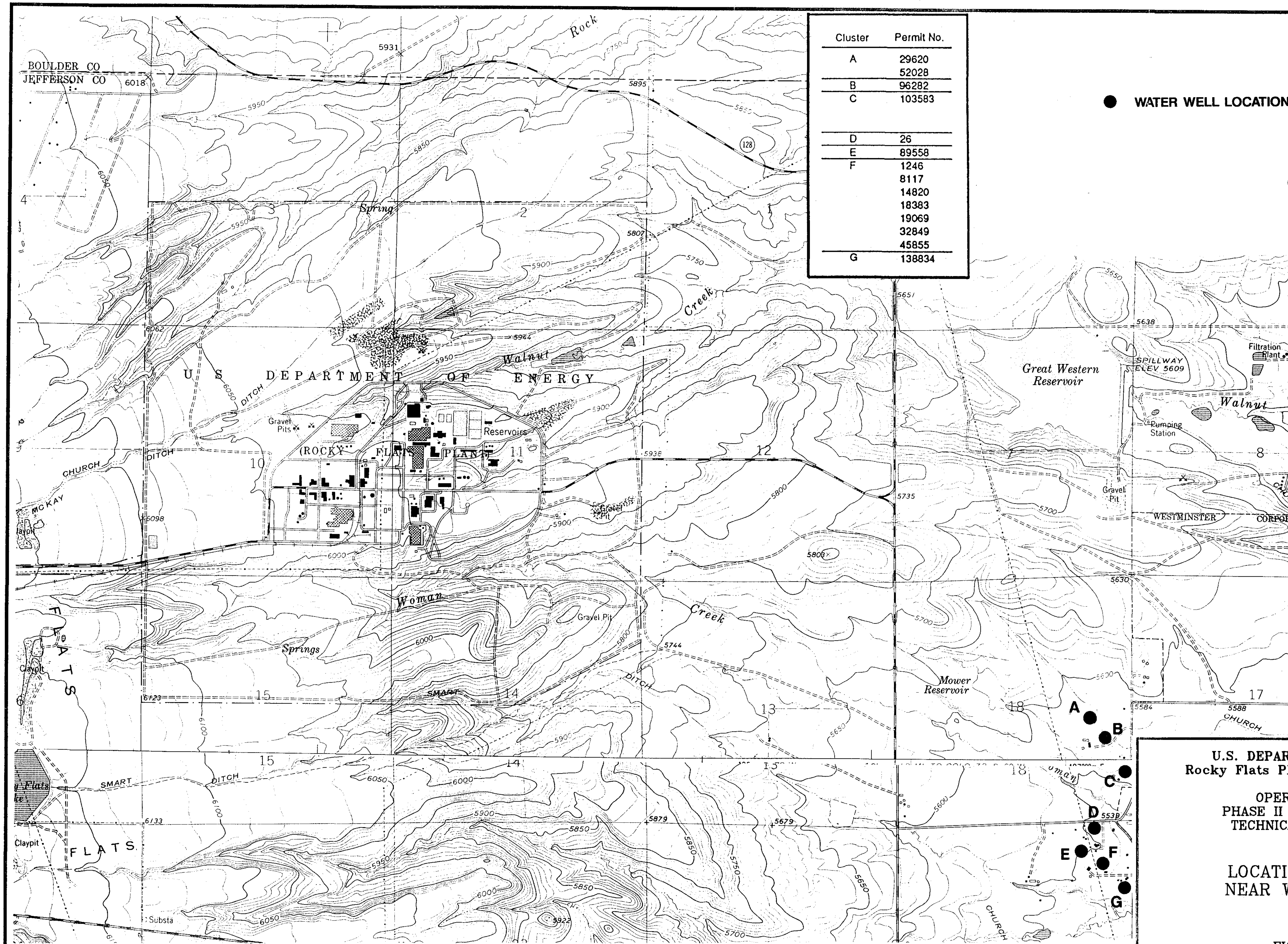
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT 2
PHASE II RFI/RI
EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

REMEDIAL INVESTIGATION AREAS AND INDIVIDUAL HAZARDOUS SUBSTANCE SITES

FIGURE 2-2

6/92

R33M003A.PJJL-062091



Cluster	Permit No.
A	29620
	52028
B	96282
C	103583
D	26
E	89558
F	1246
	8117
	14820
	18383
	19069
	32849
	45855
G	138834

● WATER WELL LOCATION

0 1000 2000 4000
SCALE IN FEET

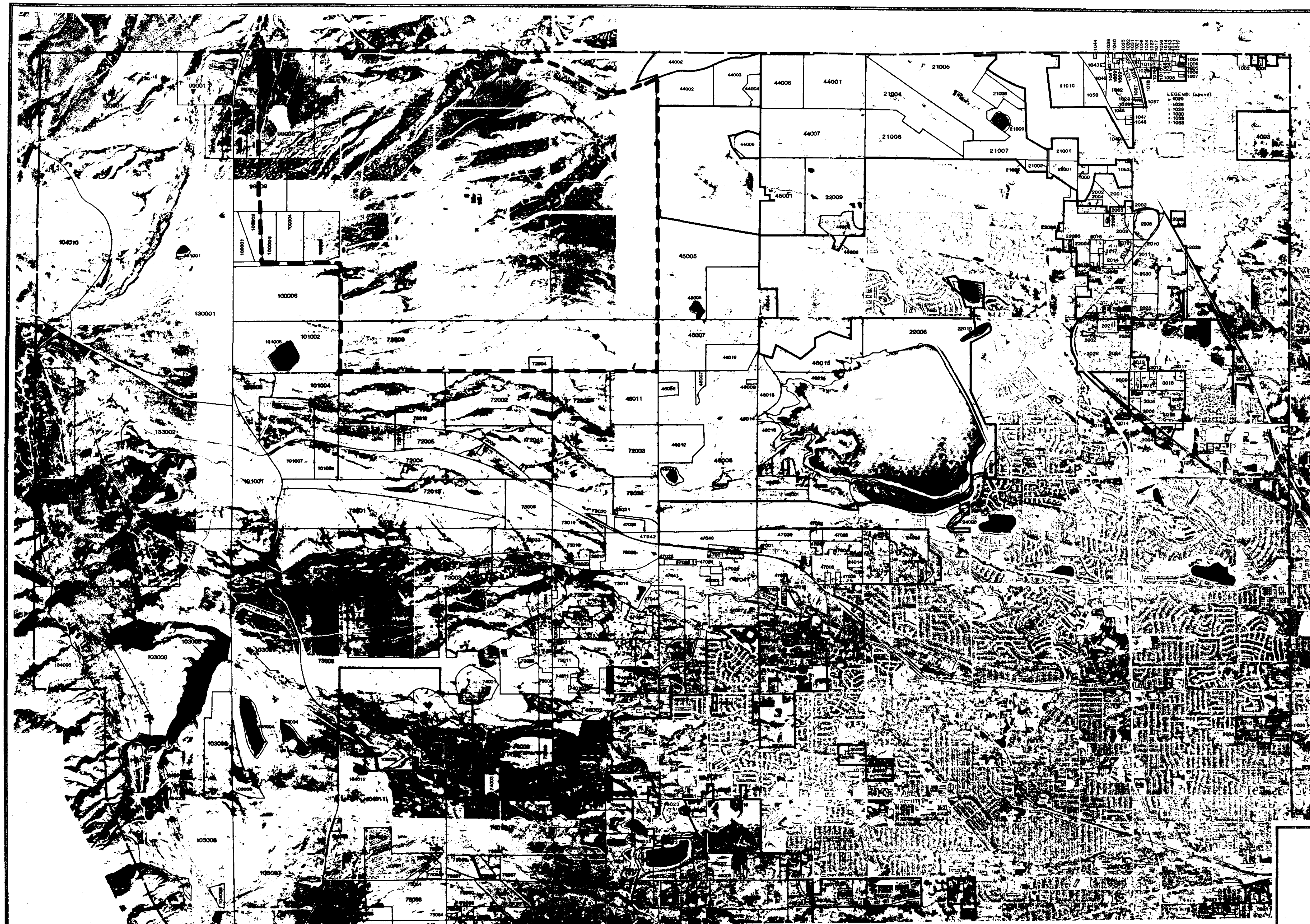
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

LOCATION OF WELLS
NEAR WOMAN CREEK

FIG. NO. 2-5 JUNE, 1992

23047025



LEGEND

- - - - ROCKY FLATS PLANT BOUNDARY

THE NUMBERED LAND-USE CODES ARE EXPLAINED IN TABLE 3-2.

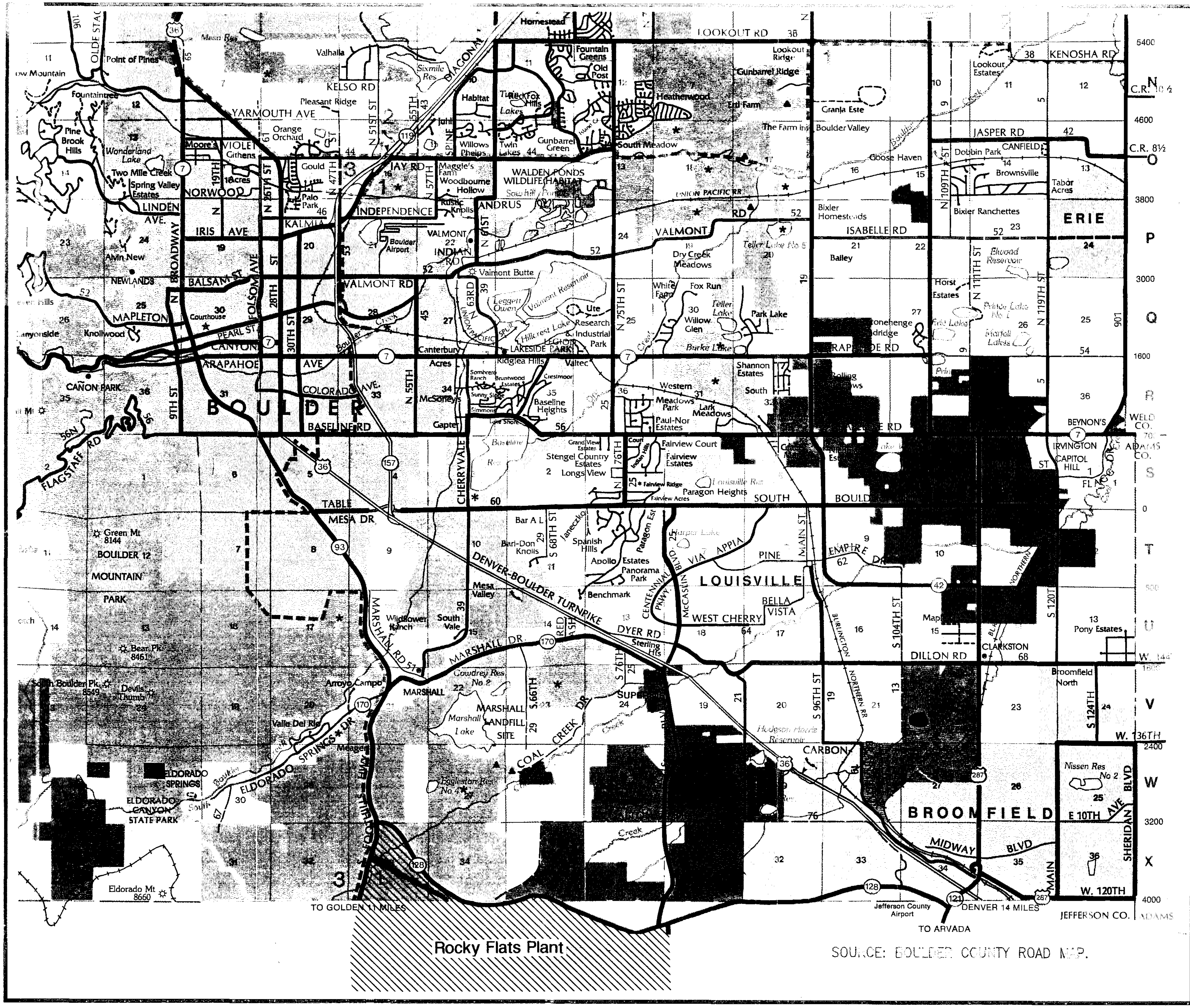
SOURCE: JEFFERSON COUNTY LAND USE INVENTORY MAP.

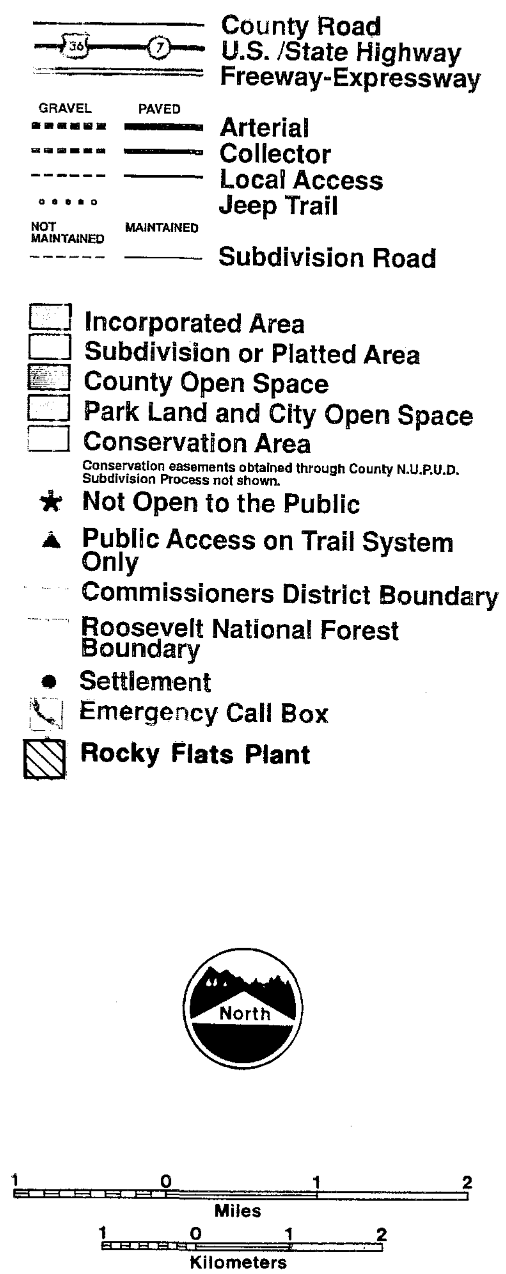
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

CURRENT LAND USE
IN JEFFERSON COUNTY

FIG. NO. 3-3 January 1993





U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

CURRENT LAND USE
IN BOULDER COUNTY

FIG. NO. 3-4 JUNE, 1992

23047034

23047035

North Plains Community Plan Study Area Summary Map

AREA	TYPE OF LAND USE
1	Cemetery
2	Existing Parks and Recreation Areas, Schools
5	Open Space, Parks and Recreation Areas, Agriculture, Ranching, and Residential up to 1 du/10 ac
6	Residential up to 4 du/ac
7	Light Industrial
8	Retail and Office
9	Residential up to 4 du/ac
10	Business Park, i.e., Office, Light Industrial
11	Aviation Use, Jefferson County Airport, Business Park, i.e., Office, Light Industrial
12	Business Park, i.e., Office, Light Industrial
13	Residential up to 2 du/ac
14	Business Park, i.e., Office, Light Industrial
15	Business Park, i.e., Office, Light Industrial
16	Residential up to 2.5 du/ac
17	Residential up to 10 du/ac
18	Infill Area. Retail, Office, Light Industrial
19	Infill Area. Retail, Office and Light Industrial, Residential up to 15 du/ac
20	Infill Area. Recreational Vehicle Parks, Retail, Office, Light Industrial, Residential up to 15 du/ac
21	Mixed Use Area. A balance of Office, Light Industrial, Retail, Community Facilities, Residential
22	Office
23	Residential up to 2.5 du/ac outside existing Retail, Office and Industrial areas
24	Residential up to 3 du/ac
25	Residential up to 3.5 du/ac
26	Residential up to 2.5 du/ac
27	Residential up to 2 du/ac adjacent to Van Bibber floodplain
28	Residential up to 2.2 du/ac
29	Residential up to 2.7 du/ac
30	West 64th Avenue and McIntyre Street Activity Center. Residential up to 15 du/ac, Retail, Office, Light Industrial
31	Golf Course, Open Space and Residential up to 4 du/ac, neighborhood-scale Retail and Office development of approximately 100,000 square feet north of West 64th Avenue
32	Residential up to 1.5 du/ac
33	Residential up to 1 du/ac
34	Open Space, Conservation because Geologic Hazard Area exists
35	Residential 1 du/5 to 35 ac, Office and limited Retail, Research and Development, Open Space and Trails
36	Residential up to 4 du/ac, Neighborhood-scale Retail and Office development up to 150,000 square feet in one quadrant of the West 58th Avenue and Colorado State Highway 93 intersection
37	Activity Center. Residential up to 10 du/ac, Light Industrial, Office, Retail, and Tourist Services
38	Residential up to 2.5 du/ac
39	Residential 1 du/5 to 35 ac
40	Residential up to 4 du/ac, Retail and Office up to a 1500 foot radius of West 64th Avenue and W-470 interchange, west of Colorado State Highway 93
41	Office, Industrial
42	Special Use Area. Office and Industrial if hazards can be mitigated
43	Residential up to 1 du/2 ac
44	Mixed Use. Office, Light Industrial, Residential up to 4 du/ac
45	Office, Industrial
46	Special Use Area. Office, Industrial if hazards can be mitigated
47	Office, Light Industrial, Golf Course, and limited Residential up to 4 du/ac
48	Office, Industrial; Retail approximately 1500 feet around the W-470 and Indiana Street and W-470 and West 104th Avenue interchanges
49	Retail, Office
50	Equestrian center, Residential 1 du/2 ac
51	Mixed Use Area. Residential up to 1 du/2 ac, Office, Light Industrial
52	Special Use Area. Rocky Flats Nuclear Facility and buffer zone

Enclaves: Residential up to 4 du/ac or existing zoning, whichever is greater. If adjacent land use is non-residential, then a similar land use could be considered provided adverse impacts are mitigated

NOTES: du/ac: dwelling units per acre

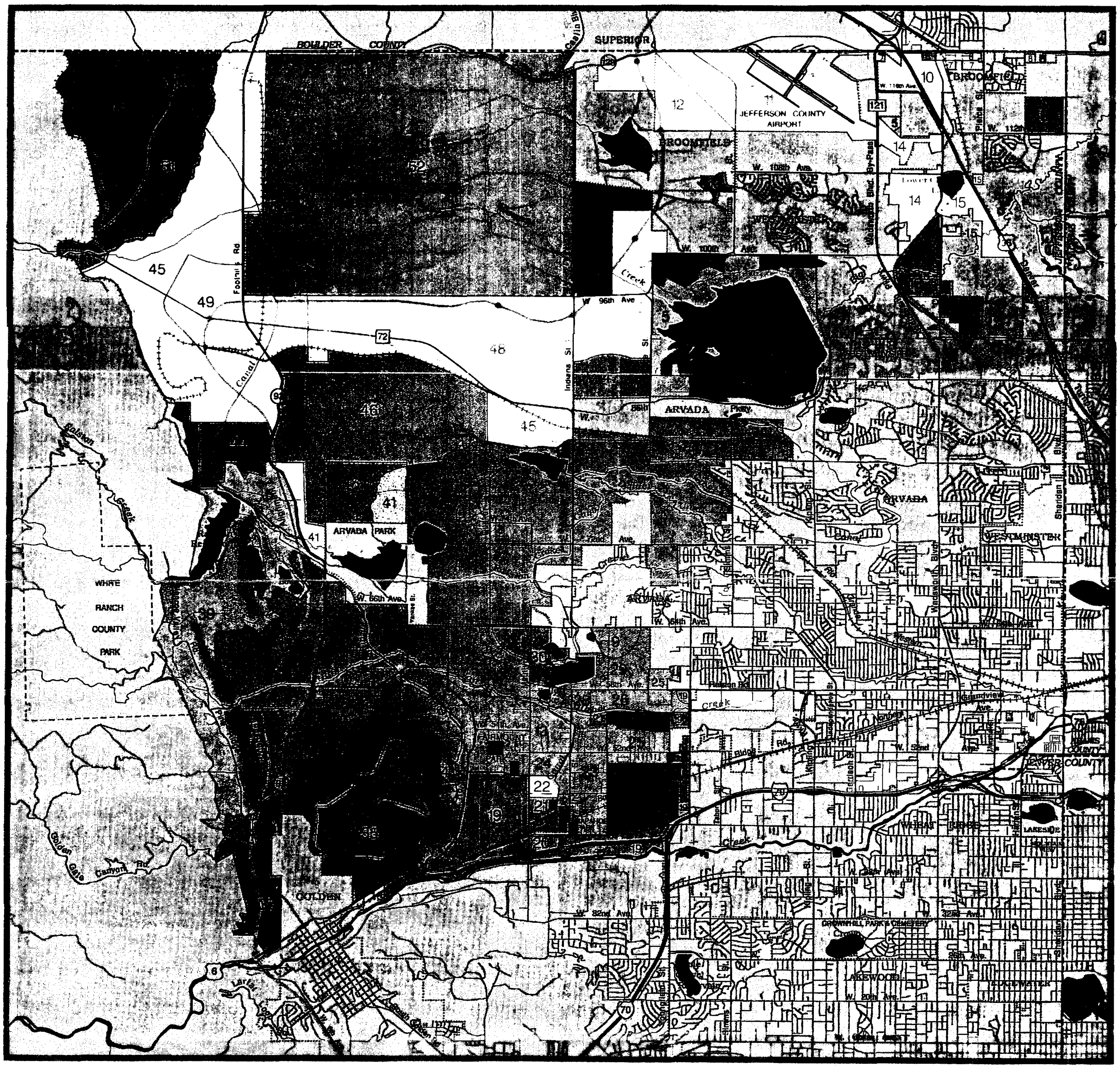
Ranching and Agriculture land uses, if consistent with current zoning, are permitted anywhere in the North Plains.

Ancillary retail is allowed in all office/industrial areas unless explicitly precluded.

Refer to specific Subarea policies for conditions affecting development in areas shown on the Summary Map and legend. In addition, the General Policies Section of this plan applies.

N

Legend:
- Nonresidential: Retail, or Office, or Industrial
- Open Space & Rural Residential 1 du/5 to 35 acres
- Enclaves
- Sanitary Landfills
- Zoned for Mining

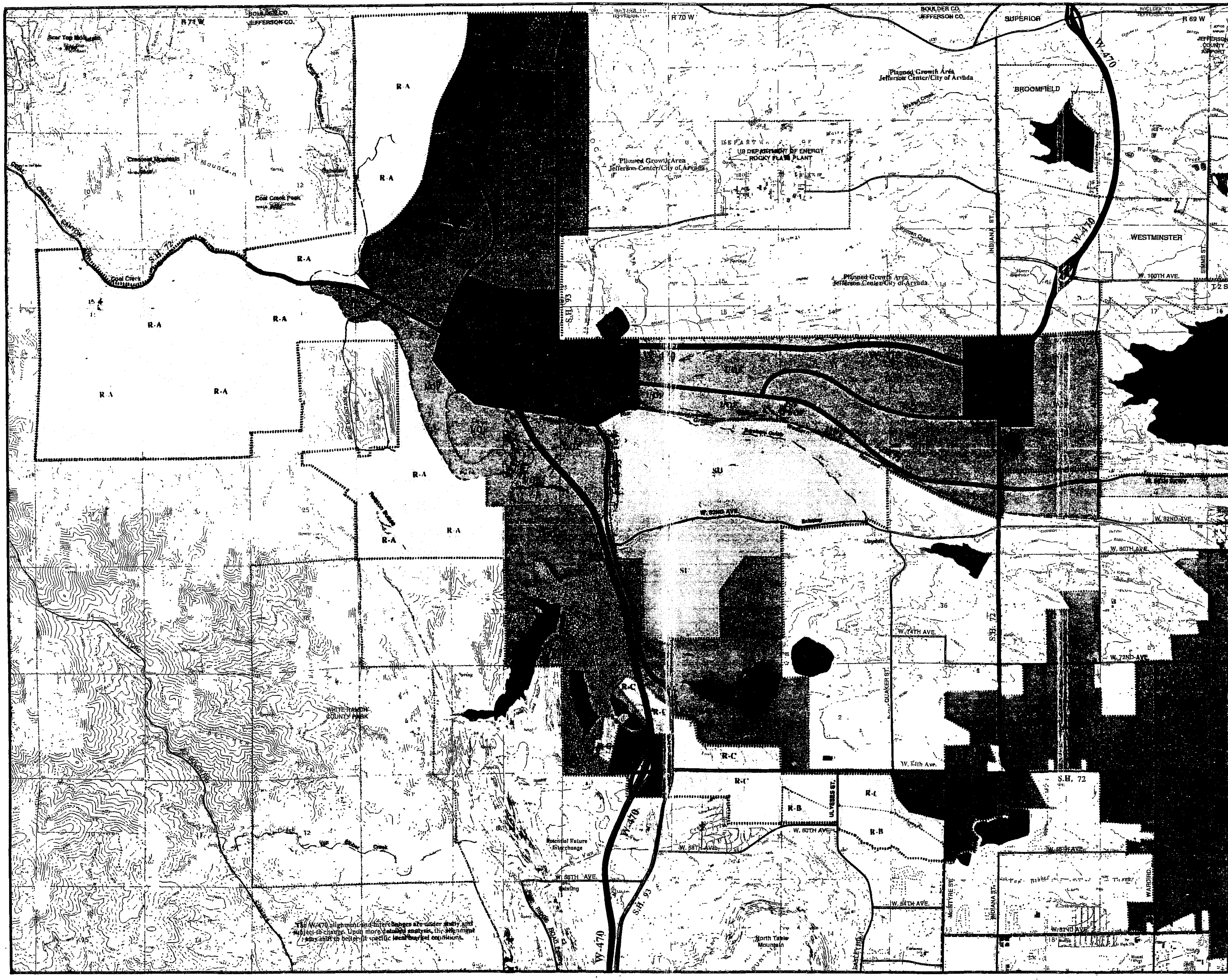


U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE
TECHNICAL MEMORANDUM

FUTURE LAND USE
IN JEFFERSON COUNTY

FIG. NO. 3-5 JUNE, 1992



JEFFERSON COUNTY

City of Arvada

JCMD NO. 1
Jefferson Center Metropolitan District No. 1

Jefferson CENTER Associates

Jefferson Center Comprehensive Development Plan

FIGURE 3-6

Legend

- Commercial and Office
- Industrial and Office
- Mixed-Use: A B or C
- R Residential (A, B or C)
- Agricultural
- Open Space
- SU Special Use
- W- 470
- Arterial Roadways
- Collector Roadways
- Existing Roadways
- Jefferson Center Development Area

SOURCE: DOE 1992.

Approval

Jefferson County
By: Marjorie E. Clement Date: 8/15/89
Title: Chairman of the Board of the County Commissioners

ATTEST:
By: Deputy Date: 8-15-89
Title: County Clerk and Recorder

City of Arvada
By: Date: 8-14-89
Title: Mayor

ATTEST:
By: Date: 8-14-89
Title: City Clerk

Jefferson Center Metropolitan District No. 1
By: Howard W. Lacy Date: 11/7/8
Title: President

ATTEST:
By: Date: 11-7-89
Title:

Jefferson Center Associates
By: Howard W. Lacy Date: 8/14/
Title: President

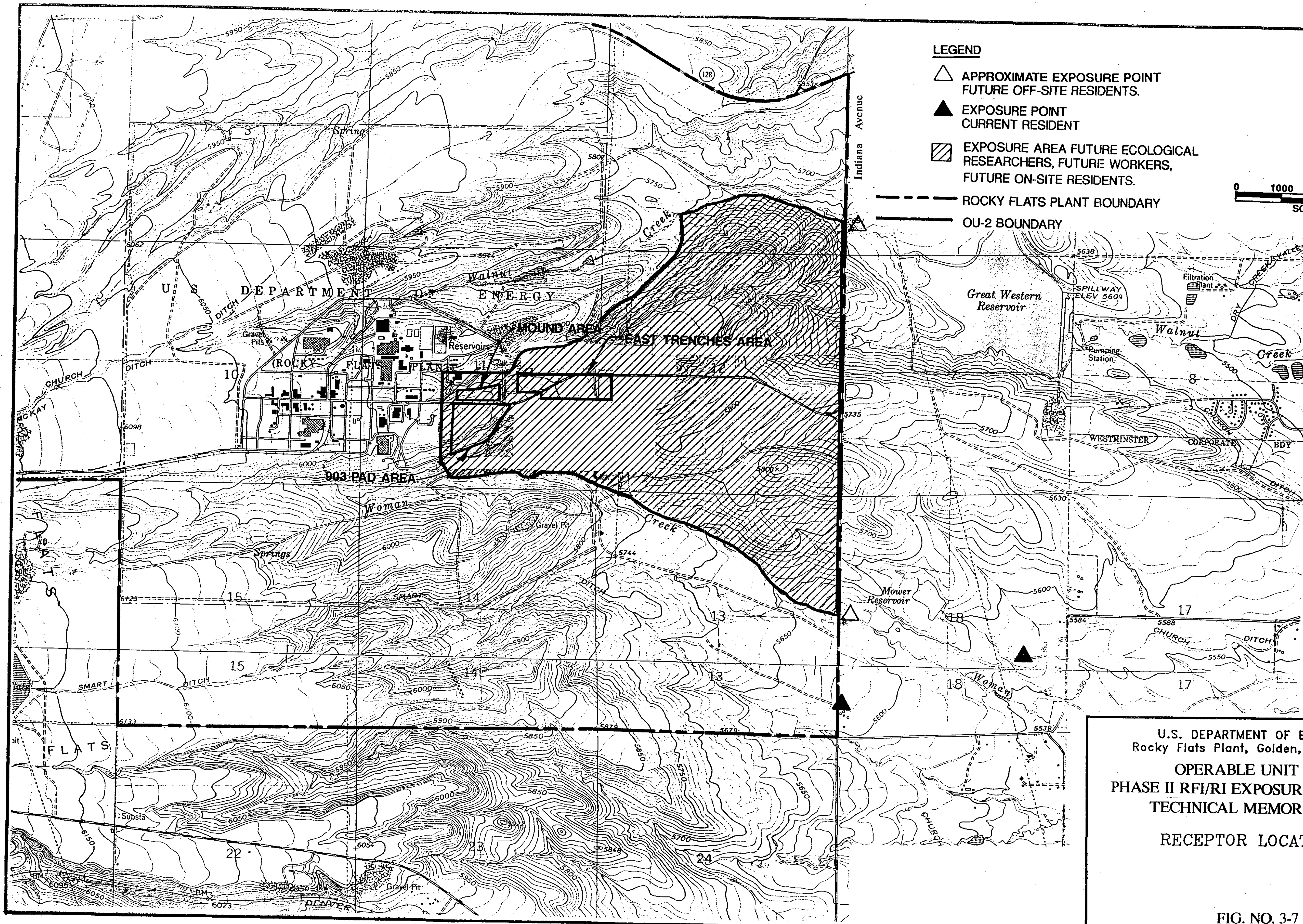
ATTEST:
By: Bruce Nelson Date: 8/14/8
Title: Vice President

NORTH

0 1,000 3,000

Scale: 1" = 2000'-0"

August 1,



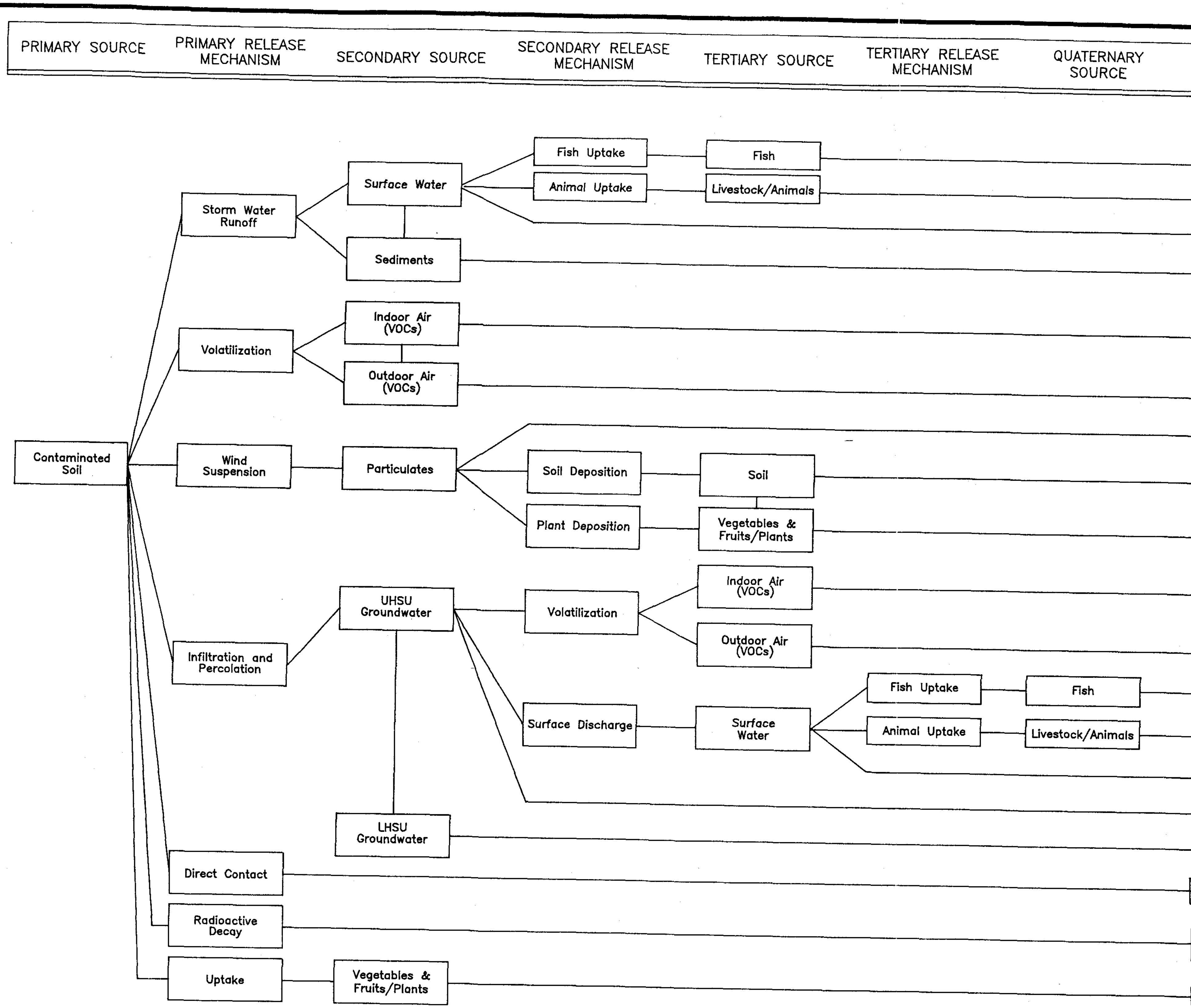
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 2
PHASE II RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

RECEPTOR LOCATIONS

FIG. NO. 3-7

January 1993



EXPOSURE ROUTE	POTENTIALLY EXPOSED HUMAN RECEPTOR							
	Current Off-site Resident	Current On-site Worker	Future On-site Office Worker	Future On-site Construction Worker	Future On-Site Ecological Researcher	Future On-Site Resident: Woman Creek	Future On-Site Resident: Walnut Creek	Future Off-site Resident
Oral	N	N	N	N	N	N	N	N
Oral	N	N	N	N	N	[illegible]	N	N
Oral	N	N	N	N	S	S	S	S
Dermal	N	N	N	N	I	I	I	I
Oral	N	N	N	N	S	S	S	S
Dermal	N	N	N	N	I	I	I	I
Inhalation	N	N	S	N	N	S	S	N
Inhalation	N	N	N	N	N	N	N	N
Inhalation	I	I	I	I	I	I	I	I
Oral	I	N	N	N	N	N	N	I
Dermal	I	N	N	N	N	N	N	I
Oral	I	N	N	N	N	I	I	I
Inhalation	N	N	S	N	N	S	S	N
Inhalation	N	N	N	N	N	N	N	N
Oral	N	N	N	N	N	N	N	N
Oral	N	N	N	N	N	N	N	N
Oral	N	N	N	N	S	S	S	S
Dermal	N	N	N	N	I	I	I	I
Oral	N	N	N	N	N	S	S	N
Oral	N	N	N	N	N	N	N	N
Dermal	N	N	N	N	N	N	N	N
Oral	N	S	S	I	S	S	S	N
Dermal	N	I	I	I	I	I	I	N
External Radiation	N	I	I	I	I	I	I	N
Oral	N	N	N	N	N	I	I	N

LEGEND
S = Significant Potential Exposure Pathway
I = Insignificant Potential Exposure Pathway
N = Negligible or Incomplete Exposure Pathway
UHSU = Upper Hydrostratigraphic Unit
LHSU = Lower Hydrostratigraphic Unit

Note: Significant and insignificant potential exposure pathways will be quantitatively evaluated.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT 2
PHASE II RFI/RI EXPOSURE ASSESSMENT
TECHNICAL MEMORANDUM

CONCEPTUAL SITE MODEL
FOR ROCKY FLATS OU2

FIG. NO. 4-1 JANUARY, 1993

RFCONC1